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MS. TAYLOR'S WALKING-STICKS: "QUEEN BESS" AND ODD "ORTHOPTERIANS" OF 1862 (MANTODEA, PHASMATODEA, DERMAPTERA, A REDUVIID HEMIPTERAN AND MANTISPID NEUROPTERA)

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Abstract

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A virtually unknown article by a Ms. Charlotte Taylor, published in 1862, contained a number of interesting (if sometimes confused) observations on certain lesser-known, North American orthopteroid, or allegedly orthopteroid, insects. Latin names, mostly original, following the principles of binominal nomenclature, were used consistently. An attempt is made to identify the species discussed and to establish synonymies where appropriate. The names *Mantis religiosa*, for the praying mantis, and *Forficula auricularia*, for the earwig observed, were misapplied to North American species, for neither had been introduced at the time. A slender, reduviid heteropteran was mistaken for a stick-insect and mantispid Neuroptera were considered to be "orthopterians". From a Canadian viewpoint, the article is particularly interesting in that it includes the second earliest record for Canada of the Common walking-stick, *Diapheromera femorata*, though the name used for it, like all Ms. Taylor's names, was a synonym. Most of her other species are now also known from S.E. Canada.

The purpose of this paper is to draw attention to a virtually unknown, early article by a Ms. Charlotte Taylor (1862) on a few lesser-known, North American orthopteroid, or allegedly orthopteroid, insects. A modicum of amateur detective work was needed, first to track down the article and then in attempting to identify the species about which the lady wrote. Of particular interest, from a Canadian viewpoint, is the second only record of a walking-stick or stick insect (Cheleutoptera, Phasmatodea) from Canada, the first in which the author used a binomen for it there. Some questions of nomenclature will also be discussed. None of Ms. Taylor's Latin names is valid, but most of her species have now been found in Canada.

The article was published more than a century-and-a-quarter ago, early in the year prior to the founding of our Society. To the best of my knowledge, it has been mentioned subsequently in the literature only twice: initially by Cowan (1865) and later by Slingerland (1900). On neither occasion were the first name or initial of the author, the *exact* title of the article, date of publication, full pagination, or range of included species of insects indicated. Both authors, who referred to the writer as "Mrs." Taylor in citing the article, were concerned exclusively with versions of folklore and anecdotal references regarding mantids. Cowan, writing soon after the original had appeared, gave an extended quotation; Slingerland, much later, gave a mere précis. The latter was, it seems, an abstract of the former account, rather than of the original, for the source is cited virtually identically and Cowan's book is mentioned by name and quoted immediately afterwards. It may be noted in passing that Charlotte Taylor's name did not appear with the text of her article, but, without indication of marital status, only in the list of contents of the publication concerned: *Harper's New Monthly Magazine*, Volume 24 (for December, 1861 to May, 1862), No. 142 (March, 1862) - each volume was for a six-month, not a full year, period. The month of publication is important in establishing the priority of the Canadian record referred to above.

The article was entitled "An orthopterian [*sic*] defense." It contained a number of interesting observations associated with eight specific names. Ms. Taylor was a colourful writer, clearly an amateur naturalist of considerable enthusiasm, if not scientific precision, and had undoubted literary ability, if no classical education. She would have been regarded as an eccentric in her day. She also seems to have been gifted with a degree of imagination and she gave binominal "Latin" names to the insects which she discussed. Some of these names were already in existence, though they were not necessarily correctly applied; some were invented for the occasion. In a couple of instances, she added what we would now term (geographical) subspecies epithets, thus forming trinomina. None of these names would seem to have been listed in any catalogue or bibliography, so that the record should be set straight.

Before proceeding further, it should be noted that, though Ms. Taylor's Latin names were not accompanied by formal descriptions, brief "definitions", of a sort, in accordance with Article 12(a) and glossary of the *International Code of Zoological Nomenclature*, 1985 were given as to the nature of the insects to which they were applied. The names may therefore, with one possible exception, be deemed "available" for the purpose of zoological nomenclature, even though the rules of classical Latin, in terms of correct adjectival suffixes, were not always adhered to. Better known authors than Ms. Taylor have erred similarly. Furthermore, though a "popular" journal, *Harper's New Monthly Magazine* can scarcely be disqualified under the *Code*, Article 8(a)(1), as being invalid as a publication medium from the standpoint of nomenclature, for it was not of an ephemeral or trivial nature. Ms. Taylor surely considered her contribution to have been "issued publicly for the purpose of providing a permanent scientific record." Neither can it be argued that, by her occasional use of trinomina, she had not "consistently applied the Principle of Binominal Nomenclature", for the use of these in a subspecific way (in this case in the modern geographical sense) does not, according to Article 11(c)(ii) of the *Code*, contravene that principle. There is thus no justification for initiating time-consuming formalities, involving submission of the case to the International Commission on Zoological Nomenclature, in order to obtain a ruling on the availability of Ms. Taylor's names or to declare them to be *nomina oblita*. These names, therefore, are treated here each on its own merits, beginning with the first of her species, which she named "*Mantis Religiosa Americana* - the 'American Soothsayer'."

Cowan (1865) abbreviated this to "the *Mantis religiosa* of America" and quoted from "Mrs." Taylor (1862) at length, particularly in respect of stories about the "pet" mantis that she called "Queen Bess". This insect she had - some years previously, it would seem - kept tethered by a silken thread tied to the posterior part of the pronotum and used it to dispose of mosquitos and other flies about her home. This anecdote is particularly interesting as it is one of the very earliest known to me that suggests a potential use of mantids in biocontrol! Cowan (1865) preceded his quotation by mentioning that "Professor [Townend] Glover, of Maryland Agricultural College, tells me he once knew a lady in Washington [D.C., where he had been employed by the U.S. Bureau of Agriculture, 1854-59], who kept a Mantis on her window..." It would seem more than likely, from the timing, that the lady was Ms. Taylor (whose entomological eccentricity would have appealed to Glover's own unorthodox outlook on life) and that we are not concerned with an earlier incident. Another, more or less contemporary reference of a similar kind is only slightly later; that of Denny (1867, mentioned also by Distant 1902). Denny's friend, A Mr. H.B. Watson, had assured him that in Melbourne, Victoria, Australia, it was "common practice to place specimens of the *Mantis* [actual genus uncertain] on the window-blinds, where they keep the room clear of flies by their incessant watchfulness for food." The earliest published reference known to me that relates to the plausibility of using mantids for the biological control of pests is to be found in a work by Ch'êng (1845). The release of *t'ang-lang* (mantids, probably *Tendora aridifolia sinensis* Saussure, 1871) was advocated with the object of destroying *tzu-fang* (probably noctuid caterpillars) attacking cultivated chrysanthemums in China.

As *Mantis religiosa* (Linnaeus, 1758), or, for that matter, *Tenodera aridifolia sinensis*, was not introduced into North American until the very end of the 19th century, and from what Ms. Taylor says about her *M. religiosa americana*, it is clear that "Queen Bess" and her relatives belonged to a well-known native species, the Carolina mantis, *Stagmomantis carolina* (Johansson, 1763). It was observed that "the shanks of the fore-legs are not so broad" as in "the *Mantis Religiosa* of Southern Europe, Asia, and Africa", so that Ms. Taylor "added *Americana* by way of distinction...They are found every where south and southwest of New Jersey. The male is not quite two inches long, and is very inferior in size and appearance to the female. There are varieties of brown and gray colors..." We may therefore establish the following synonymy:

> *Gryllus carolinus* Johansson *in* Linnaeus, 1763:386 = *Mantis carolina*, Burmeister, 1838:538 = *Mantis religiosa americana* Taylor, 1862:491, **syn. nov.** = *Mantis religiosa* of America, Cowan, 1865:88 = ***Stagmomantis carolina*** (Johansson, 1763), Saussure, 1869:65.

It is interesting to note that Ms. Taylor was astute enough to observe that the mantids "have a countercheck constantly attending in the shape of a pretty Ichneumon fly, which deposits an egg in each of [t]he[i]rs" and "If the fly is inattentive, or not at hand, the [egg] capsule soon hardens, and the mantes [*sic*] are safe." The hymenopteran was presumably a species of *Podagrion* (Chalcidoidea, Podagrionidae). Ms. Taylor concluded her account of mantids with a fairly detailed description of oviposition and the formation of the ootheca, or "capsule" - with some peculiar aberrations in the case of the latter involving the drawing out of the matrix by means of the jaws! Earlier in the article, she told her readers how to capture, keep, tether and feed mantids, mentioning that they will consume raw pigeon flesh in lieu of insects. This may be the earliest record of meat-eating by mantids.[1] She also related various legends, folklore and tales about the insect, with varying degrees of accuracy, before discussing the exploits of "Queen Bess".

The second of Ms. Taylor's insects is the first of three "walking-sticks". She called it "The *Phasma Fragilis Americana* - 'Fragile American Phasma', or, familiarly, 'Walking-stick'." The latter is, of course, the usual common name given by Americans to Cheleutoptera (Phasmatodea) in general, but it may be noted that Ms. Taylor did not apply it to the other two species discussed and to which she gave a different generic name, *Spectrum* - which is now deemed "unavailable" for the purposes of zoological nomenclature. One may therefore deduce that she believed that she was discussing a distinctly different kind of insect, though her account is garbled, confusing real stick insects with a carnivorous "walking-stick". The insect in question was said to be like "a twiggy stick...very dark brown with lines of black, like old wood. It is believed to be entirely herbivorous; but I have fed them, found in Connecticut, for weeks at a time, on aphides." There can be almost no doubt that the insect was, in fact, a very slender reduviid bug, the stick-like *Emesaya brevipennis brevipennis* (Say, 1828) (Emesinae). This species attains 35 mm or more in length and is very widely distributed in the eastern and central United States of America from Massachusetts to Florida and from Iowa and Missouri to Texas. It also occurs in southern Ontario (e.g., it has been taken at Harrow, 1 September 1951, E.J. LeRoux; 2♂♂ in Lyman Museum). We may give the following synonymy for the record:

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[1] It is not cited by Kevan (1985), who mentions one or two other such references when introducing the subject of mantids preying upon small vertebrates. Kevan also omits a reference by Alexander (1888, cited also by Distant, 1902) to a mantis, probably of the same species, attacking a hummingbird in South Carolina, with fatal results for the bird.

> *Cimex longipes* DeGeer, 1773:352, pl. 35 fig. 16, 17 [junior homonym of *C. longipes* Linnaeus, 1767:724] = *Ploiaria brevipennis* Say, 1828:[72], pl. 47 = *Emesa filum* [of Fabricius, doubtfully], Griffith *et al.*, 1832:244, pl. 97 fig. 3[2] = *Emesa pia* Amyot & Audinet-Serville, 1843:394 = *Phasma fragilis americana* Taylor, 1862:493, **syn. nov.** = *Dmesa* [*sic*, for *Emesa*] *choktawana* Kirkcaldy, 1909:388 [*nom. nov.* for *E. brevipennis* of Dohrn, 1860, incorrectly regarded as differing from Say's species; see McAtee & Malloch, 1925:78] = ***Emesaya brevipennis brevipennis*** (Say, 1828), McAtee & Malloch, 1925:79, pl. 6 fig. 121-125, pl. 7 fig 136-138 [trinomen not used in captions to plates; genus *Emesaya* erected pp. 6, 10, 12, 74].

Ms. Taylor's account includes the erroneous hearsay that the insects "are represented as biting off the tops of buds, eating holes in leaves, and destroying bean and corn crops in the Middle States." A large, true stick-insect, *Megaphasma denticrus* (Stål, 1875), does occur in that region and is occasionally numerous, for example on vines, but it is scarcely likely to have "destroyed crops". It would certainly not feed on aphids! Neither would a smaller stick-insect that occurs on lower vegetation in Connecticut, *Diapheromera blatchleyi atlantica* (Davis, 1923), a species so similar to Ms. Taylor's second walking-stick that she probably would not have observed the difference and certainly would not have given it a different generic name! *D. b. blatchleyi* (Caudell, 1905) is more widely distributed, but seems to be arboreal for the most part. Ms. Taylor makes some other misleading or ambiguous statements, but she observes that the insects "are very lazy, quiet, inoffensive creatures". According to Say (1828) their movements are slow and unsteady. He also observed that they were found in "outhouses" - presumably meaning any small, unheated structures, in the original, English, rather than in the modern, restricted, North American sense! Indeed they are usually taken in such places, though they do occur on vegetation, etc., also. They are quite often gregarious. Mr. Taylor presumably exaggerated when she wrote, "Sometimes they make their appearance in certain places in myriads, and then disappear again for years.", but the observation does corroborate the assumed identity of her species. Other supporting points include the statements that the eggs were glued to plants (stick-insect eggs are not), that the insects moulted only four times, and that they lacked the ability to regenerate lost appendages (which stick-insects possess). Unfortunately, however, it was stated that they had "not even a rudiment of a wing", whereas *E. brevipennis* is brachypterous, though the abbreviated wings could perhaps have been missed, being narrow and usually closely adpressed to the body.

The second of Ms. Taylor's "walking-sticks" is readily identifiable and is, indeed, a true stick insect. From a Canadian viewpoint, this is the most interesting of her species, because it was said to be "numerous some years ago at the Falls of Niagara [whether on the New York or the Ontario side is not indicated], and a specimen was found in a garden at Montreal [Quebec]. No other locality was mentioned. The species was named "The *Spectrum Betulla* [*sic*, for *betulae*] - 'Birch-Tree Spectrum'. It was added that it was the *S. Femoratum* of Say. Just why it was given another name is unclear, for Ms. Taylor expressed no doubt as to the identity, as she did in the case of the next species, nor had she cause to do so. It would seem probable that Article 11(e) of the *International Code of*

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[2] *E. filum* Fabricius, 1794, is an oriental species; the caption to the figure reads "*Emesa flium ? Fab.*"; in the index, p. 786, the name is misprinted "Emera [*sic*] filum" and the identification is corrected to "brevipennis - of Mr. *Say*."

Zoological Nomenclature, 1985, renders Ms. Taylor's name "unavailable" because "a name first published as junior synonym is not thereby made available unless prior to 1961 it has been treated as an available name...", but then, Ms. Taylor herself, though no-one else, treated the name as if it were available, a situation for which the *Code* does not seem to make provision. For the sake of argument, we may cite the following synonymy:

> *Spectrum femoratum* Say, 1824:297; 1828:[4], pl. 37 = *Diapheromera sayi* Gray, 1835:18 = *Bacteria (Bacunculus) femorata*, Burmeister, 1838: 566 = *Diapheromera femorata*, Harris, 1841:119 = *Phasma* [sp.], Gibb, 1859:127 = *Spectrum betulla* [emend. *betulae*] Taylor, 1862:493, **syn. nov.** = *S[pectrum] femoratum* of Say, Taylor, 1862:493 = *Bacunculus femoratus*, Uhler *in* Harris, 1862:146 = ***Diapheromera femorata*** (Say, 1824), Scudder, 1862:284.

Ms. Taylor said that these insects were strictly herbivorous and lived "in forests on the highest birch-trees" and that they were "the color of dead leaves - a dingy brown, with a slight streak down the back. They generally go in pairs. The female is larger, but not so stout as the male...and the [egg] capsule appears precisely like two rough pieces of bark bent into shape...compact, impervious to water, and full of eggs." Some of the account was, of course, imprecise and some was pure fancy. The species is not confined to the tops of trees, though these are the favoured habitats of the adults; it is not common on birch (*Betula*), preferring oak (*Quercus*), though it is found on trees of many genera (and, in the immature stages, on lower vegetation); the male is even more slender (not stouter) than the female; and the eggs, which are scattered singly in ground litter, bear no resemblance to the form described. Indeed, one is hard-put to imagine what it was that Ms. Taylor mistook for stick insect eggs - even mantid oothecae would not have been present in the regions mentioned until the following century!

Diapheromera femorata was originally described by Say (1824), in the invalid genus *Spectrum*, from a hickory tree (*Carya*) at "the Falls of Niagara", presumably on the New York side (the type locality), as well as from an unrecorded location the Missouri River. The two occurrences were repeated a few years later (Say 1828) when records for New Jersey and Massachusetts were added. *Diapheromera*, initially a monotypic genus, was erected by Gray (1835) to accommodate the same species under the name of "*D. Sayi*," but Burmeister (1838) called it *Bacteria (Bacunculus) femorata*. Harris (1841) recorded it again for new England under its current name. The first Canadian record was only incidental; Gibb (1859) mentioning the insect in passing, as "*Phasma*" only, noted that it had been found on Mount Royal, Montreal, Quebec. The editor of the journal tentatively suggested in a footnote (correctly as it happened) that it was Say's *Spectrum femoratum*.

The earliest record for Canada in which the author himself gave a specific name has been assumed hitherto to be that of Scudder (1862), who reported a specimen of *D. femorata* from the Selkirk Settlements on the Red River, in what is now southeastern Manitoba. This record, incidentally, was cited erroneously by Riegert (1980:45) as referring to "1 praying mantis" (see Vickery and Kevan 1983:298; information edited out of Vickery and Kevan, 1986, along with most bibliographic references). It now transpires that the Taylor (1862) article was published several months before that of Scudder (1862), so the Montreal, if not the Falls of Niagara, record takes precedence as the first binominal record by any author for Canada. The first such record actually by a Canadian, however, came a little later: that of Ritchie (1867), also from the Montreal area, on a basswood tree (*Tilia*) to the north side of Mount Royal, and at Logan's Farm nearby, September, 1865. The latter locality has long since disappeared under urban sprawl. Vickery and Kevan (1983:300) called this the first Canadian record to use a specific name, but their phraseology was ambiguous: "Canadian" referred to the actual authorship and not to the record as such, the journal in which it was published (*cf.* Scudder 1862) or the editorial footnote to Gibb (1859). Ritchie

(1867) used Say's original, outmoded name, *Spectrum femoratum*, as in that footnote.[3]

Before proceeding further, it might be appropriate to question whether the records of *D. femorata* given by Ms. Taylor were original or plagiarized from Say (1824, or 1828) and Gibb (1859). As regards "the Falls of Niagara", omission of the other localities mentioned by Say, together with the assertion that the species had been numerous on birches (Say's was of a single specimen on hickory), would suggest originality. In the case of Montreal, Gibb (1859) made no mention of a garden, Ms. Taylor omitted Mount Royal, and the chances of her having read Gibb's paper would seem remote, so that her record for Montreal was presumably authentic also. We do not know that she visited either locality herself, though she does seem to have travelled quite widely in the eastern United States of America.

The last of Ms. Taylor's walking-sticks as named by her "*Spectrum Palmeus* [*sic*, for *palmae*] - 'Palmetto Spectrum'." The lady said that she did not "feel assured that this is the *Spectrum Bevittatum* [*sic*] of Say, though there is certainly very small difference. It is only found far south; I have never seen it north of the Carolinas." From most of what was said about this insect, it was indeed *Spectrum bivittatum* Say, 1828, the Two-striped walking-stick, described originally from an orange tree on Cumberland Island, Georgia, and also recorded from palmetto palms in either Georgia or Florida, or both (the text is ambiguous). *S. bivittatum* is, however, a junior synonym of *Phasma buprestoides* Houttuyn *in* Stoll', 1813 - transferred to the genus *Anisomorpha* by Gray (1835). As that species barely reaches as far north as South Carolina, Ms. Taylor's hesitancy over the name might be explained, for in most of the Carolinas, *A. buprestoides* is replaced by a very similar species *A. ferruginea* (Palissot de Beauvois, 1817[4]). Here there is no question of the Taylor name being a junior synonym. We may give the synonymy as follows:

> *Phasma buprestoides* Houttuyn *in* Stoll', 1813:68, pl. XXIII Fig. 87 (*cf.* Register) = *Phasma vermicularis* Houttuyn *in* Stoll', 1813:68, pl. XXIII fig. 88 (*cf.* Register) = *Spectrum bivittatum* Say, 1828:[7], pl. 38 = *Anisomorpha buprestoides*, Gray, 1835:19 = *Spectrum palmeus* [emend. *palmae*] Taylor, 1862:493, **syn. nov.** = *Spectrum bevittatum* [*sic*] of Say, Taylor, 1862:493 = ***Anisomorpha buprestoides*** (Houttuyn *in* Stoll', 1813).

Ms. Taylor, as did Say (1828), discussed the association of the insect with palmetto fronds and noted that "if you lift one [of the insects] up suddenly, the gummy substance or digested food, will ooze out round the segments. It has a most peculiar pungent smell at first; but as you familiarize yourself to it it becomes highly aromatic...This odor is very peculiar, and you will never forget it when once you have inhaled it." Say (1828) had already reported that a Mr. G. Peale had, more accurately, "remarked that when taken they discharged a milky fluid, from two pores of the thorax, diffusing a strong odour", which was compared to that of a species of Compositae, said to be *Gnaphalium* and assumed to constitute "at least part of its diet". Both authors were, of course, referring to the insect's defensive secretion, which it often ejects forcibly for some distance. Neither seems to have been aware that the secretion, if it enters the human eye, may be dangerous, causing temporary blindness for up to several days. Both authors remark on the disparity of the sizes of the sexes which is such that one would doubt that a single species was involved. Indeed, Houttuyn (*in* Stoll' 1813) gave the male a different name, *vermicularis* (like a little worm). Both authors also noted that the insects are generally found in pairs.

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[3] Note: in Vickery and Kevan (1983), p. 298, lines 16 and 17 (misprinted through an oversight in proof-reading) should be deleted as being out of sequence, repetitious and partially inaccurate.

[4] Usually given as 1805, though this refers only to the first two "*livraisons*" of Palissot de Beauvois' publication, parts of which continued to appear until 1821, after his death (see Vickery and Kevan, 1983:699).

Ms. Taylor correctly observed that the eggs were not laid on palmetto plants, but incorrectly stated that they were deposited on broad-leaved trees, such as magnolias, "in a light-brown many ribbed capsule." In fact, the eggs are scattered singly on to the ground, as in most stick insects. The "capsule" referred to may well have been the ootheca of a mantis, probably *Gonatista grisea* (Fabricius, 1793). The apparent disappearance of females when ready to oviposit and the consequent predominance of males were noted. This was followed by a rather fanciful account of male aggressiveness and the dispatching by females of "the remainder of the other unhappy sex - their services being no longer required." While males of some larger species of stick insects are, at least when caged, apparently aggressive and may kill each other (Hsiung 1987), they do not have "carnivorous propensities" such as are attributed to those of the present species by Ms. Taylor. It would seem more than likely that she got some of her notes on mantids involved in her account of this stick insect.

A. ***buprestoides*** is of minor interest from a Canadian viewpoint only because an adventive pair, imported from Florida, was found in Montreal in November, 1953, as noted by Vickery and Kevan (1984). These authors warned those who might encounter the species in imported produce against the potentially harmful secretion of the insect.

Ms. Taylor followed her accounts of presumed and actual species of stick insects with three more on species of "*Mantispa*", which she termed "Mantis of the air". She noted that many entomologist [including Say (1825), whom she would seem to have read] preferred "to locate them among the Neuroptera" - where, indeed, Say correctly maintained that they belonged. Her ideas on the principles of systematics were, however, *passé*: "As the insect's principal characteristic should designate its class - which in this instance pronounces the close affinity between Mantis and Mantispa in the construction of their front legs", she considered the latter to be a "sub-genus" of the former. Hence we have Neuroptera (as well as Hemiptera) included with the "orthopterian" insects. In her day, of course, and until much later, insects known as Neuroptera constituted a large and very heterogenous assemblage of unrelated orders, most of which, as she pointed out, had [like dragonflies, mayflies, stoneflies and caddisflies] aquatic immature stages. She maintained that these "Mantispae", the food of which was said to be "small processionary and social caterpillars called 'canker-worms'", were arboreal and moulted, "as the others do", four times in the course of development. She also asserted that the immature stages were very active, running about on trees, resembling large ants, often not gaining "their brilliant colors until at the last moulting with their wings." Thus it is clear that, when discussing the immature stages, she was not writing about those of mantispids, which were unknown at the time.

The life-histories of these insects are, of course, now known to be holometabolous (as with other true neuropteroids), the larval stages being spent, except for the early "triungulin", entirely within the egg-sacs of spiders, upon the young of which they prey. For reviews of mantispid biology, see Redborg and MacLeod (1984) and New (1986). When adults are ready to emerge after completing the pupal stadium, there is a brief pre-imaginal "pharate" phase in which the insect bites its way out of the cocoon and through the spider egg-sac to wander for a short distance before undergoing the final moult. When Say (1825) observed that mantispids "are not quiescent in the nymph state, or that condition which corresponds to the chrysalis state of a butterfly, but they remain active, as is the larva", one must assume that he referred only to the pharate condition, nothing being known of the immature stages generally at the time. Ms. Taylor may have wrongly deduced otherwise. We will now consider her three *Mantispa* species.

The first of these she named "The *Mantispa Denarius* [*sic*, for *denaria*] - 'Ten-toothed Mantispa'" and mentioned that it was found near Philadelphia and as far north as New York. "The most favorable time is to watch for them on the trunks of trees, before they attain their wings...", presumably meaning the pharate stage referred to above. There then followed a brief account of how to feed them and a description of the coloration, which was very varied. Without repeating what was said, it would seem that the only mantispid that would fit the bill would be *Climaciella brunnea* (Say, 1824), which occurs widely throughout the United States of America, southwards into northern South American and northwards into Canada, where it is reported by Robert (1949) for both Quebec and Ontario. It occurs in at least five different colour-forms which mimic *Polistes*-wasp species. For coloured illustrations, see Opler (1981) who gives further information and references, as, for example, do Throne (1972) and Boyden (1984), Redborg and MacLeod (1984) and New (1986).

We may synonymize Ms. Taylor's species as follows:

> *Mantispa brunnea* Say, 1824:309; 1825:[50], pl. 25 fig. 2 [♂], 3 [♀] = *Mantispa varia* Erichson, 1839:161 = *Mantispa denarius* [emend. *denaria*] Taylor, 1862:494, **syn. nov.** = *Mantispa burquei* Provancher, 1875:247 = ***Climaciella brunnea*** (Say, 1824), Enderlein, 1910:360, 361.

Ms. Taylor's descriptions of the [egg] capsule and the eggs bear no relation to those of any mantispid and may be ignored.

Her second species she named "The *Mantispa Aureus* [*sic*, for *aurea*] - 'Golden Mantispa'" and is said to be "shaded in the brightest of golden yellow" with a dark green stripe "dotted with gold" down its back. "The wings, where the bands are the darkest, are yellow, the spaces between merely shaded from the effulgence of the whole." This rather colourful description of a mantispid from "the Middle and Southern States" would not seem applicable to any species other than *Mantispa interrupta* Say, 1825 - and that is rather stretching a point! Thus:

> *Mantispa interrupta* Say, 1825:[52], pl. 25 fig. 1 = *Mantispa aureus* [emend. *aurea*] Taylor, 1862:494, **syn. nov.** = ***Mantispa interrupta*** Say, 1825.

This species is widely distributed in the eastern half of the United States of America, extending further westwards in the south. In the north, it reaches southern Quebec (Robert 1949) and Ontario. Again, Ms. Taylor's accounts of the larvae and [egg] capsule were entirely fanciful.

When it comes to the last of Ms. Taylor's "*Mantispa*" species, "The *Mantispa Gulosus* [*sic*, for *gulosa*] - 'Gluttonous Mantispa'", I must confess that I am at a loss to identify it. Firstly, "Those long-legged crane-flies would disappear very magically before it", suggesting that they ere eaten. No mantispid could cope with crane-flies (Tipulidae), which would be too large and awkward to handle. Secondly, "The larvae were found hidden away between the grains of some wheat ears. Only one came to perfection,...and it came out with a bluish-black body, brown wings, red eyes, and yellowish legs, with brown lines intersecting them." Perhaps if one assumed that the crane-flies were only "scared" away and that the "larvae" were found singly on different wheat ears, and that they were really pharate adults, one might accept this account as referring to one of the morphs of *Climaciella brunnea*, already discussed, but this would be a wild guess. We can only declare the name to be very doubtful; thus:

> *Mantispa gulosus* [emend. *gulosa*] Taylor, 1862:294 = **nomen dubium.**

It seems not unlikely that Ms. Taylor confused her "gluttonous mantispa" with a species of smaller true mantid, for she went on to say that "Subsequently a number of [egg] capsules were found on the joints of the long cane-grass of the Southern swamp, from which issued...the same larvae...I liberated the whole colony in the garden..." Perhaps, on this occasion, she was dealing with the slender, grass-inhabiting mantid *Oligonicella scudderi* (Saussure 1870).

Ms. Taylor concluded her article with a discussion of "The *Forficula Auricularia* - 'The Ear-wig'". Much of what she wrote when referring to folklore and various other matters indeed related to *F. auricularia* Linnaeus, 1758, the Common European earwig, but not when referring to North America. There is no evidence to suggest that the species, now so widespread and familiar there, became established in the United States of America until the 20th century, as discussed by Vickery and Kevan (1983). Nevertheless, Ms. Taylor indicated that she was familiar with earwigs there, so that, unless the dubious report of Fieber (1853), noted by Vickery and Kevan (1983), had any basis of fact (which is extremely doubtful), she must have referred to species other than *F. auricularia*. Indeed, she mentioned in passing that "We have several varieties in this country [U.S.A.], but they have attracted very little attention hitherto, or their depredations have been insignificant. A pretty spotted variety is found in Louisiana on the sugar plantations." This doubtless referred to a species of *Doru*, presumably *D. taeniatum* (Dohrn, 1862), the elytra of which are pale laterally so that the insect might seem spotted.

Ms. Taylor discussed, amongst other things, earwigs having been raised by her on aphids and as having been made the subject of an investigation into the life-history, maternal habits, including brooding and incubation, and the way in which the progeny finally devoured the remains of the mother. This species was said to be "about an inch long, of a blackish-brown color; the thorax is lead-colored, except in the centre, which is the color of the body. The wing-covers are of a dark brown...The under wings are very pretty and large..." Of the few species of earwig that Ms. Taylor is likely to have been able to observe, only *Vostox brunneipennis* (Audinet-Serville, 1838), the Brow-winged earwig, would seem to have the appropriate characters and distribution, though it is not usually very common and is a little smaller than indicated (and than *F. auricularia*).

Perhaps, in conclusion, it would be appropriate to mention that Ms. Taylor's objective in publishing the article was to indicate that all insects were not to be abhorred as pests and that some had admirable qualities from a human standpoint. She opened her article with a quotation from William Shakespeare's *The Winter's Tale*, Act II, Scene 1 - though she did not give the source and mis-spelt the first word of the second line as "You"!

"I will tell it softly;
Yond crickets shall not hear it."

She concluded, referring particularly to earwigs, but with all her "orthopterians" in mind:

> "They are very timid, harmless, ill-treated, misunderstood, much-abused insects, for whom I henceforth bespeak your liberality and charity, feeling most assured - and I hope you will agree with me - that the Useful is ever the Beautiful."

Amen.

References

Alexander, G.W. 1888. [A mantis and a bird. (Letter).] Proceedings of the Elliot Society for natural History, 2:195-196. [Extract quoted, 1888, Nature, London, 38:303.]

Amyot, C.B.J. and Audinet-Serville, J.G. 1843. Histoire Naturelle des Insectes. Hémiptères. Nouvelles Suites a Buffon, [19]. Paris; Roret; 76 + 675 + 6 pp. + 12 pl.

Boyden, T.C. 1984. Mimicry, predation and potential pollination by the mantispid, *Climaciella brunnea* var. *instablilis* (Say) (Mantispidae: Neuroptera). Journal of New York entomological Society, 91[1983]:508-511.

Burmeister, H. 1838. Kaukerfe, *Gymnognatha* [Erste Hälfte; *vulgo* Orthoptera.] Handbuch der Entomologie. Berlin; Theod. Chr. Fridr. Enslin, 2(2):I-VIII, 397-756.

Ch'êng, Tai-An. 1845. Hsi Wu Chü Lüeh [= Western Wu Chrysanthemum Album]. [See Huang, Hsing-Tsung, 1986. Plants and Insects in Man's Service. *In* Needham, J., Lu, Gwei-Djen, and Huang, Hsing-Tsung. Science and Civilization in China. Cambridge *et al.*; Cambridge University Press, 6:471-553 (547).]

Cowan, F. 1865. Curious Facts in the History of Insects: including spiders and scorpions... Philadelphia; J.B. Lippincott & Co.:xvi + 396 pp.

DeGeer, C. 1773. Mémoires pour servir à l'Histoire des Insectes. Stockholm; Pierre Hesselberg. 3:VIII + 696 + 2 pp. + 44 pl.

Denny, H. 1867. Hatching of the *Mantis* in England. Annals and Magazine of Natural History, 3:144.

Distant, W.L. 1902. Fam. VI. Mantidae. Insecta Transvaaliensia. A Contribution to the Entomology of South Africa. London; W.L. Distant, I [all published] (2):28-42, pl. II (part).

Enderlein, G. 1910. Klassification der Mantispiden nach dem Material des Stettiner Zoologischen Museums. Stettiner entomologische Zeitschift, 71:341-379.

Erichson, F.W. 1839. Beitraege zu einer Monographie von Mantispa. Germar's Zeitschift fur Entomologie, 1:147-173, 1 pl.

Fieber, F.X. 1853. Synopsis der europäischen Orthoptera mit besonderer Rücksicht auf die in Böhmen vorkommenden Arten als Auszug aus dem Drucke vorliegenden Werke, "Die europäischen Orthoptera" (Fortsetzung). Lotos, 3:115-129.

Gibb, G. 1859. On the Generation of Sounds by Canadian Insects. Canadian Naturalist and Geologist, 4:121-130.

Gray, G.R. 1835. Synopsis of the Species of Insects belonging to the Family of Phasmidae. London; Longman, Rees, Brown, Green and Longman:iv + 48 pp.

Griffith, E., Pidgeon, E., and Gray, G. 1832. Supplement on the Order Hemiptera. *In* The Class Insecta: 2. The animal Kingdom arranged in conformity with its organization by Baron Cuvier...with supplementary additions to each order. London; Whittaker, Treacher, and Co., 15:229-293, pl. 92, 93, 97, 91, 116, 90, 138, 108, 109.

Harris, T.W. 1841. A Report on the Insects of Massachusetts injurious to vegetation. Cambridge, Massachusetts; Folsom, Wells and Thurton:viii + 459 pp.

Harris, T.W. 1862 (posthumous). A Treatise on some of the insects injurious to vegetation. (Third Edition; C.L. Flint, Ed.). Boston, Massachusetts; William White:xii + 640 pp.., VIII pl.

Hsiung, C.-C. 1987. Aspects of the biology of the Melanesian stick-insect *Eurycantha calacrata* Lucan (Cheleutoptera: Phasmatidae). Journal of Natural History, 21:1241-1250.

Kevan, D.K.McE. 1985. The mantis and the serpent. Entomologist's monthly Magazine, 121:1-8.

Kirkcaldy, G.W. 1909. Hemiptera, old and new, No. 2. Canadian Entomologist, 41:388-392.

Linnaeus, C. [as C. von Linné]. 1763. Centuria Insectorum rariorum. Amoenitates Academicae Uppsaliae, 6:384-415.

Linnaeus, C. [as C. a Linné] 1767. Systema Naturae per regna tria naturae secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. (Ed. XII). Holmiae [= Stockholm]; Laur. Salvius, 1(2):[i-ii], 533-1327, (1) - (37).

McAtee, W.L. and Malloch, J.R. 1925. Revision of the American bugs of the reduviid subfamily Ploiariinae. Proceedings of the Unites States National Museum, 67:1-153, pl. 1-9.

New, T.R. 1986. A review of the biology of Neuroptera Planipennia. Neuroptera International (Supplement) 1:i-vi, 1-57.

Opler, P.A. 1981. Polymorphic Mimicry of Polistine Wasps by a Neo-tropical Neuropteran. Biotropica, 13:165-176.

Provancher, L. 1875. Descriptions des plusieurs insects nouveaux. Neuroptère. Naturaliste canadien, 7:247-251.

Redborg, K.E. and MacLeod, E.G. 1984. The Developmental Ecology of *Mantispa uhleri* Banks (Neuroptera: Mantispidae). Illinois biological Monographs, 53:i-x, 1-131.

Riegert, P.W. 1980. From Arsenic to DDT: A History of Entomology of Western Canada. Toronto, Buffalo, London; University of Toronto Press:xii + 551 pp.

Ritchie, A.S. 1867. Notes on the "*Spectrum femoratum*". Canadian Naturalist and Geologist, (New Series) 3:66-69. [No. 1 of this volume was dated Feb. 1866, but not published until 12.I.1867; see p. 80].

Robert, A. 1949. Les Mantispidés de la Province de Québec (Plannipennes). Naturaliste canadien, 76:5-14.

Saussure, H. de, 1869. Essai d'un Système de Mantides. Mitthheilungen der schweizerischen entomologishen Gesellschaft, 3:49-73.

Say, T. 1824. Appendix, Part 1, Natural History. I. Zoology. *In* Keating, W.H. Narrative of an Expedition to the Source of St. Peter's River, Lake Winnepeek, Lake of the Woods, etc., etc., performed in the year 1823, by order of the Hon. John Caldwell Calhoun, Secretary of War, under the command of Stephen Harriman Long...Philadelphia; Government Printer. 2:254-378.

Say, T. 1825. American Entomology, or Descriptions of the Insects of North America, illustrated by Coloured Figures from original drawings executed from nature. Philadelphia Museum; Samuel Augustus Mitchell. 2:II + 125 unnumbered pp. + pl. 19-36.

Say, T. 1828. *Idem*. 3: II + 123 unnumbered pp. + pl. 37-54.

Scudder, S.H. 1862. List of Orthoptera collected on a trip from Assiniboia to Cumberland. Canadian Naturalist and Geologist (New Series) 7:283-288.

Slingerland, M.V. 1900. A new beneficial insect in America. The common European praying mantis. *Mantis religiosa* Linnaeus. Order Orthoptera; Family Mantidae. Bulletin of the entomological Division of Cornell University agricultural Experiment Station, 185:35-47, 1 pl.

Stoll', C. 1813 (posthumous; Ed. M. Houttuyn). Natuurlijke en naar het leven nauwkeurige gekleurde Afbeeldingen en Beschrijvingen der Spoken, Wandelende Bladen, Sabelspringhanen, Krekels, Trekspinghanen en Kakkerlakken, in alle vier deelen der wereld: Europa, Asia, Afrika en Amerika huishoudende, bij een verzameld en beschreven. Amsterdam; J.C. Sepp et Fils. 1:[ii] + 79 pp., XXV pl.; 2:[ii] + 28 + 42 + 8 + 14 (10 - 14 - Register), XIII + XXIII + IV + V pl.

Taylor, C. 1862. An orthopterian defense. Harper's new monthly Magazine, 24:490-496.

Throne, A.L. 1972. The Neuroptera - Suborder Planipennia of Wisconsin Part III - Mantispidae, Ascalaphidae, Myrmeleontidae and Coniopterygidae. Great Lakes Entomologist, 5:119-128.

Vickery, V.R. and Kevan, D.K.McE. 1983. A monograph of the orthopteroid insects of Canada and adjacent regions. Memoirs of the Lyman entomological Museum and Research Laboratory, 13(1):[I-II], i-xxii, 1-679, frontispiece, pl. I-VIII.

Vickery, V.R. and Kevan, D.K.McE. 1984. "The Orthopteroid Insects of Canada and Adjacent Regions." Further Corrigenda, etc. [by D.K.McE. Kevan]. St.-Anne de Bellevue, Québec; Lyman Entomological Museum and Research Laboratory: 8 pp. [Issued to all recipients of the above for insertion.]

Vickery, V.R. and Kevan, D.K.McE. 1986. The Insects and Arachnids of Canada Part 14 - The Grasshoppers, Crickets, and Related Insects of Canada and Adjacent Regions - Ulonata: Dermaptera, Cheleutoptera, Notoptera, Dictuoptera, Grylloptera, and Orthoptera. Research Branch Agriculture Canada Publications. 1777 [of 1985]:1-918.

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A NEW SPECIES OF *SPELOBIA* SPULER ASSOCIATED WITH FENS IN YUKON, ALASKA AND NORTHEASTERN NORTH AMERICA (DIPTERA: SPHAEROCERIDAE)

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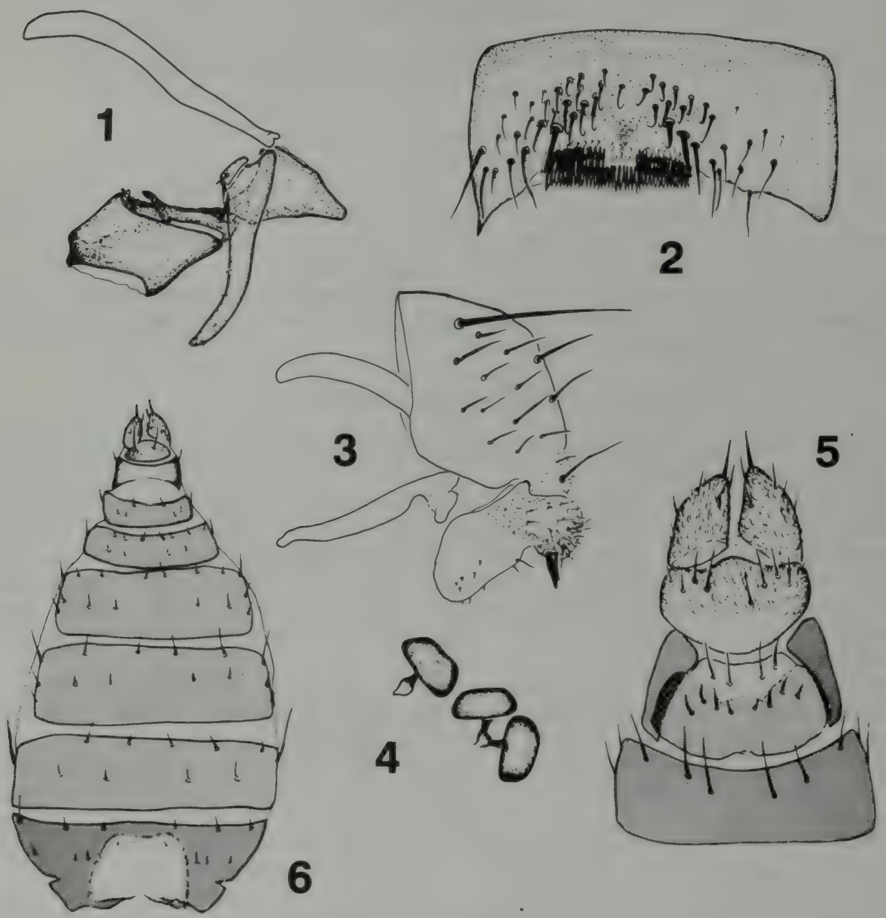
Introduction

Spelobia algida new species is described from Ontario, New Hampshire, Yukon and Alaska. Most of the type specimens are from fens near cold springs, which suggests that this species is characteristic of cold fens. *S. algida* keys out to *S. multihama* Marshall in Marshall (1985), but differs in having only a single surstylar spur (i.e. lacks the stout anterior bristles) and in lacking the carinate lobe that characterizes the fifth sternite of male *S. multihama*. *S. algida* is smaller than *S. multihama*, and has only 6 rows of acrostichal setulae instead of the 9 found in *S. multihama*.

Spelobia (Spelobia) algida new species

Description: Body length 1.7 - 1.9mm; color dark brown to black palpi yellow, sutures and stem of halter pale brown.
Head: Postocellar bristles equal in length to ocellar setulae. Lower frons narrowly and indistinctly reddish; orbits, interfrontal strips and most of interfrontal plate silvery, intervening areas forming a narrow, dull black M-shape. Interfrontal plate *ca.* 1.2X as high as wide, bordered by 3 interfrontal bristles, upper 2 long and subequal, lower pair smaller. Lunule brown, triangular; face broadly carinate, concave on lower half. Arista long-pubescent, usually 1.9 - 2.0X eye height; eye height 2.0 - 3.8X genal height, variable (see notes on variation).
Thorax: Dorsocentral bristles in 2 pairs, posterior pair 2X length of anterior pair, subequal to scutellar length. Acrostichal setulae in 6 rows between anterior dorsocentral bristles; prescutellar acrostichals slightly enlarged, twice as long as other acrostichals. Katepisternum with a posterodorsal bristle reaching 2/3 of way to wing base, and a small anterior bristle. Mid-tibia posterodorsally with only small setulae on proximal half, distal posterodorsal bristle inserted slightly above level of distal dorsal bristle. Tarsomere 1 of midleg 0.5X length of tibia. Wing length 2.1 - 2.2X width; membrane brownish; second costal sector 1.2X length of third; R4+5 straight. Alula oval, width less than length of crossvein dm-cu.
Abdomen: Syntergite 1+2 slightly longer than tergite 3, syntergite with a large, anteromedial, pale-pigmented area which normally extends 3/4 of way to hind margin of tergite 2 (Fig. 6), pale area smaller in Yukon specimens. Pleural membrane with strong setulae on segments 3, 4, and 5.
Male terminalia: Posteromedial comb of sternite 5 with an unbroken posterior row and an anterior row broken into 2 widely separated parts; area anterior to comb with hook-tipped bristles, some of which are stout (Fig. 2). Epandrium with long dorsolateral bristles. Cercus setulose, with one relatively long bristle (Fig. 3). Surstylus with a large, sparsely setulose anterior part and a smaller, setulose posterior part bearing the single surstylar spur. Basiphallus tapered posteriorly; distiphallus simple, dorsal sclerite heavily sclerotized, saddle-like and covering most of distiphallus (Fig. 1). Paramere simple, tapered.
Female terminalia: Tergite 8 desclerotized medially. Epiproct broad, short; entirely microsetulose; the usual pair of bristles present and widely separated. Cercus large, tapered along outer surface, with short, stout medial dorsal and apical bristles, the latter very stout and shorter than cercus (Fig. 5). Sternite 8 with a large depigmented posteromedial area.

Hypoproct broad, setulose except anterior edge. Spermathecae short-cylindrical, with short stems (Fig. 4).



FIGURES 1-6. *Spelobia algida* new species (Ontario specimens). 1. Aedeagus and associated structures, left lateral; 2. Male sternite 5; 3. Terminalia of male, left lateral; 4. Spermathecae; 5. Female terminalia, ventral; 6. Female abdomen, dorsal.

Variation: One of the specimens examined, a male from New Hampshire, has an additional pair of basal scutellar bristles similar to those characteristic of *S. maculipennis* (Spuler) and *S. abundans* (Spuler). The specimens from Yukon differ from the other samples in having a less extensive depigmented area on syntergite 1+2 and having a longer apical bristle on the female cercus. Eye heights of the specimens from Yukon were also generally less (2.0 -

3.2X genal height) than those recorded for other localities (3.2 - 3.8X, usually closer to 3.8X). Although this extent of variation is unusual in the Limosininae, the presence of Alaskan specimens more similar to the eastern specimens than are the specimens from Yukon, and the uniformity of male genitalia across the range, supports the view that the eastern and western specimens are the same species.

Holotype ♂ (Canadian National Collection) and 6 paratypes (4♂, 2♀, University of Guelph Collection): CANADA. ONTARIO. Algonquin Provincial Park, E. of Kearney, Jubilee Lake, in *Sphagnum* near source of small spring, under moose dung, 19.v.1985, S.A. Marshall.

Other paratypes: CANADA. YUKON. Dempster Highway, km. 141, dung trap in *Sphagnum* along spring, 6-11.vii.1985, S.A. Marshall (6♂, 2♀, University of Guelph Collection, Canadian National Collection); Dempster Highway, km 28, dung trap in tundra near fen pond, near dwarf birch, 6-11.vii.1985, S.A. Marshall (1♂, University of Guelph Collection). UNITED STATES. ALASKA. Richardson Highway, km. 146, vacuumed from moose dung in bog, 18.vi.1987, S.A. Marshall (3♂, 1♀, University of Guelph collection); Houston, 24.vi-19.viii.1984, malaise-FIT, spruce/birch/moss, S. & J. Peck (1♂). NEW HAMPSHIRE. Coos Co., Norton Pool, 3 mi. & 1 mi. NE East Inlet Dam, 9-26.v. & 22.viii-12.ix.1986, FIT, D.S. Chandler (University of New Hampshire, 2♂).

Comments: *S. algida*, named for its association with cold and wet places, has been most often collected from fens associated with freshwater springs. It is predicted that this species will prove characteristic of this specific microhabitat, and that further specimens will be found in cold spring fens such as the type habitat. This species does not seem to occur in other peatlands, as no specimens have been found in the course of comprehensive sampling of bogs and poor fens in Alberta and Ontario. The specimens taken in New Hampshire were taken in the course of an extensive survey using flight-intercept traps (D. Chandler, University of New Hampshire). The large samples of Sphaeroceridae taken during the survey in New Hampshire include many species with generally boreal distributions.

Phylogenetic placement: Most of the 42 North American species of *Spelobia* fit into the strongly supported species groups named by Marshall (1985, Fig. 22). *S. algida*, like the similar *S. multihama* (and four other species), lacks the synapomorphies defining any of these major groups. Some of the similarities between *S. algida* and *S. multihama*, especially characters of sternite 5 including the enlarged, hook-tipped bristles flanking a pale posteromedial area, are probably synapomorphic. *S. multihama*, known from Ontario, Vermont and New Hampshire, is a rare species apparently associated with leaf-litter.

References

Marshall, S.A. 1985. A revision of the genus *Spelobia* Spuler (Diptera: Sphaeroceridae) in North America and Mexico. Transactions of the American Entomological Society, 111:1-101).

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BIOLOGICAL NOTES ON A BIRCH LEAF EDGEMINER, *SCOLIONEURA BETULETI* (HYMENOPTERA:TENTHREDINIDAE), NEW TO NORTH AMERICA

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Abstract

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Scolioneura betuleti (Klug.), a European birch leaf edgeminer, was first discovered in southern Ontario in 1983. Observations on its life cycle and some immature stages are described.

Introduction

Adults of *Scolioneura betuleti* (Klug.) were first collected in Canada in 1983 near Newmarket, Ontario. The adults were first identified in 1984 and the species was first reported as *S. betuleti* by Evans *et al.* (1985). We believe this to be the first North American record of the species, which is the spring unit of a complex of two species in Europe, *S. betuleti* and S. *betulae* Zadd. (Goulet, personal communications, 1986, 1987). The taxonomic relationship of these insects is incompletely defined as we are awaiting the results of studies of the holotypes in Europe, but the species in Ontario has been tentatively identified as *S. betuleti* (Klug.) (Goulet, Biological Research Centre [BRC] lot # 83-1054, Forest Insect and Disease Survey [FIDS] # 835-0097). A study of this leaf edgeminer was begun in 1985 and continued throughout the summer of 1986 near the city of Newmarket in central Ontario.

Methods and Observations

Detailed methods, where pertinent, are described in appropriate places throughout the text.

Distribution and Host

Benson (1952) reported that *S. betuleti* (=*betulae* Zadd.) is a common birch leafminer throughout Britain and Ireland and northern and central Europe. Collections made in Ontario since 1983, from two locations near Newmarket and one near Brighton, are the first records of this species in North America (Fig. 1). Collections of *S. betuleti* for study purposes were made 4.3 km west of Newmarket.

Both *S. betuleti* and *S. betulae* mine the leaves of many species of birch in Europe (Ripper 1931; Benson 1952; Lorenz and Kraus 1957; Zombori 1978), but in Ontario the species has been found only on *Betula pendula* Roth and *B. pubescens* Ehrh., both European birches. At the study site (Fig. 2), 16 individual roadside trees were infested with both *S. betuleti* and *Fenusa pusilla* (Lep.) (Hymenoptera: Tenthredinidae), a common birch leafminer in southern Ontario. The overall average defoliation, determined by the percentage of leaves mined, was estimated to be 12.4% and ranged from 11.3% to 30.0%. On average, the trees were approximately 4.6 m in height. Native white birch, *B. papyrifera* Marsh., and poplar, *Populus spp.*, were the most common trees in the area.

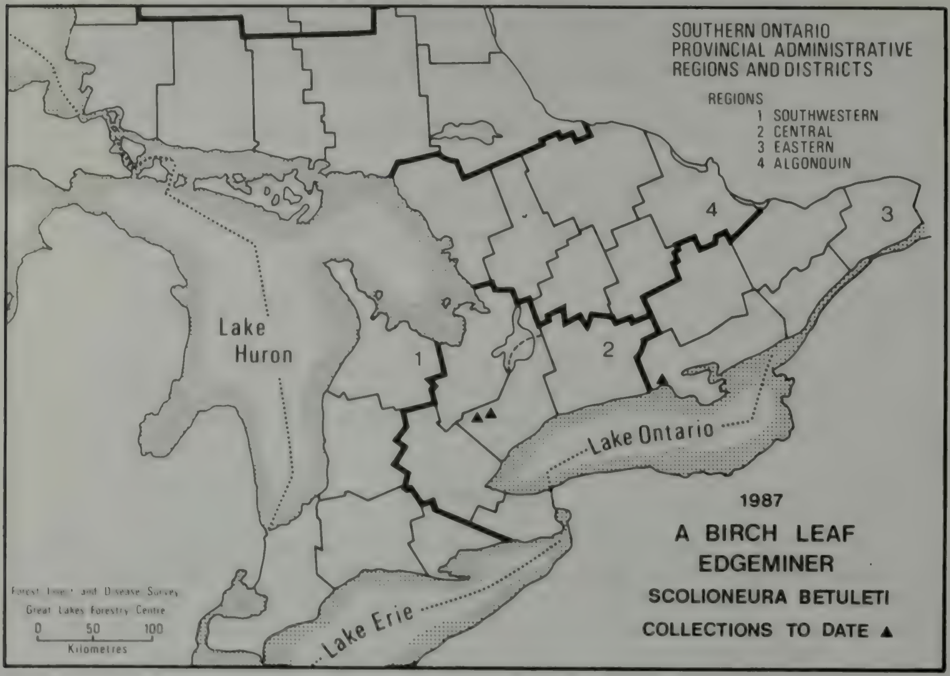

FIGURE 1. Collection sites for *Scolioneura betuleti* (Klug.) as of 1987.

Life History and Habits

S. betuleti is univoltine in Ontario. During the years in which the insect was studied, adults were collected from the first of May to the first week in June. In the field, adults were observed mating shortly after their emergence during the second week of May.

The females use their ovipositor to make a slit in the leaf tissue near the margin of the leaf into which the eggs are deposited (Fig. 3). Eggs are located at the edge of a leaf tooth or near the base of the leaf near the petiole (where there are no teeth). Eggs can be found from late May to early June. The oval swelling caused by the egg is equally noticeable on the upper and lower surfaces of the leaf. The mean number of eggs laid per leaf was 2 (±0.194 (S.E.), n=58), but as many as 10 eggs per leaf were observed in one case. Larger leaves tended to support more eggs, as was observed by Tuomi *et al.* (1980).

The larvae feed singly in the mine, with their venters towards the upper surface of the leaf. They are found from late May to late June. Measurements of the head widths of reared larvae and of cast head capsules in vacant mines (Table I) indicate that the larvae molt five times before cutting a hole in the lower surface of the leaf epidermis and dropping to the ground to pupate.

It was not possible to rear *S. betuleti* from pupae to imago, although larvae could be kept alive until the end of the sixth instar. From the European literature it is believed that the larva spins a cylindrical cocoon, made from the soil and secretions of the spinneret, with pupation occurring in the spring, as for *S. betulae* (Ripper 1931; Zombori 1978).

The blotch mine (Fig. 4) made by *S. betuleti* resembles that described by Hering (1957, p.180) and Lorenz and Kraus (1957), and is similar, in Europe, to the mines of *S. betulae* (Ripper 1931; Hering 1957). In Ontario, the mines of *S. betuleti* are similar to those made by *Messa nana* Klug. (Hymenoptera: Tenthredinidae), which is also a birch leaf edgeminer

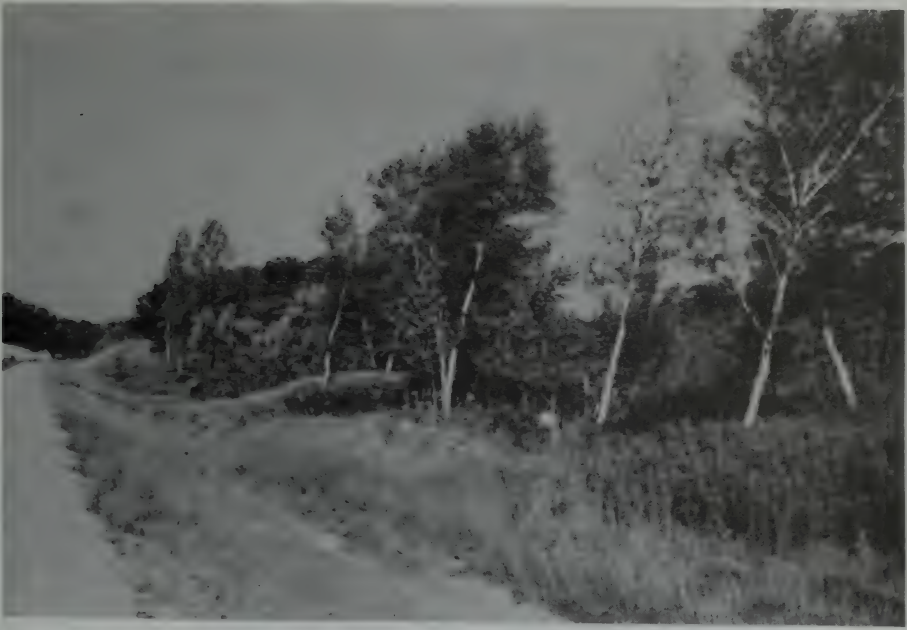

FIGURE 2. The study site near Newmarket, Ontario.

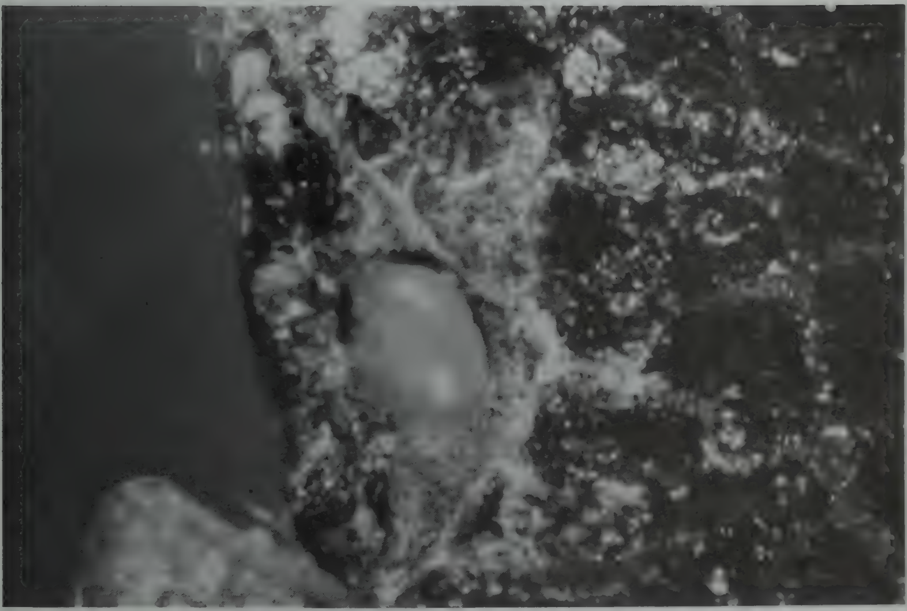

FIGURE 3. An exposed egg of *S. betuleti* in European birch (*Betula pendula*) leaf tissue.

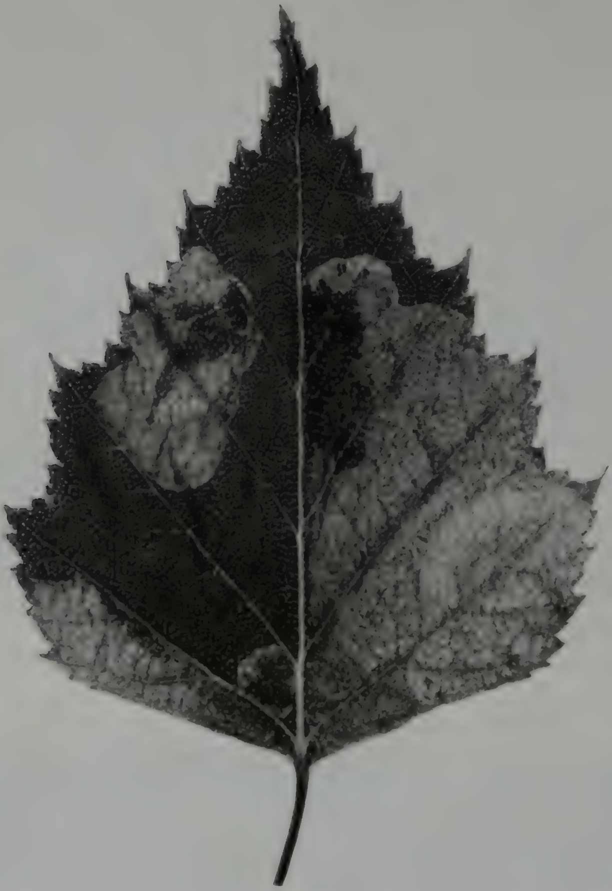

FIGURE 4. Feeding damage (mining) on the upper surface of a leaf of European birch.

(Lindquist and Thomson 1970). *Messa nana* initially constructs a short tunnel away from the leaf edge before expanding the mine (Hering 1957; DeClerck and Shorthouse 1985), whereas *S. betuleti* mines follow the edge of the leaf and then expand into a blotch mine. Furthermore, frass is packed tightly at the initial point of feeding. Thereafter, patches of frass can be observed throughout the mine and accumulated at the edges. As was found at the study site, mines made by other larvae of the same species and by any *F. pusilla* that are present often coalesce; initially, the larvae appear to coexist.

Description of Immature Stages

Head capsule widths were measured for individuals of known instars from reared material and from larvae of unknown instars collected from the field (see Table I). Only typical larval instars from reared material were described.

TABLE I. Mean head capsule widths of *S. betuleti* larvae

			Head capsule widths (mm)	
Instar		n	Mean ± SE	Range
I	Reared	13	0.335 ± 0.048	0.313 — 0.410
	Field	13	0.381 ± 0.015	0.240 — 0.458
II	Reared	6	0.505 ± 0.009	0.428 — 0.530
	Field	21	0.530 ± 0.007	0.480 — 0.576
III	Reared	5	0.646 ± 0.004	0.627 — 0.651
	Field	28	0.642 ± 0.005	0.602 — 0.699
IV	Reared	4	0.837 ± 0.020	0.771 — 0.867
	Field	51	0.817 ± 0.007	0.720 — 0.888
V	Reared	11	1.102 ± 0.019	0.967 — 1.157
	Field	47	1.002 ± 0.014	0.904 — 1.320
VI	Reared	9	1.080 ± 0.019	1.000 — 1.175
	Field	13	1.090 ± 0.020	0.988 — 1.205

Eggs. Eggs of *S. betuleti* are translucent white, and unsculptured. The mean egg length was 0.601 mm ± 0.014 (range of 0.450 - 0.659) and the mean diameter was 0.485 mm ± 0.008 (range of 0.410 - 0.640) (n=14).

Larvae. In the first five stages, the larva is slightly depressed and its integument is white. The yellowish, chitinized head is prognathous; however, during the later instars (3 to 5) it becomes dark laterally. Antennae have 4 segments. The thoracic legs are well developed, with five segments and a claw positioned laterad. The thoracic segments are wider than the abdominal ones, and the larva tapers caudad. Larvapods are present on abdominal segments 2 to 8, and the anal legs are joined.

First-instar Larva. A pair of yellowish, latero-ventral sclerites are noticeable on thoracic segment 1. On thoracic segments 2 and 3, and on abdominal segment 1, there are light brown to yellowish, mid-ventral sclerites.

Second-instar Larva. The thoracic shield becomes brownish laterally and posteriorly. The joined anal legs are surrounded by a dark, brown, sclerotized ring that is opened posteriorly and somewhat pointed antero-ventrally.

Third-instar Larva. All markings that appeared in previous instars become darker. The yellowish head turns brown laterally and draws slightly into the prothorax. Sclerites on the legs are dark brown. Abdominal segment 9 has a pair of brown ventral tubercles that may be noticeable in the second instar but is much more evident in the third. Brown markings may appear on the surpedal area on abdominal segments 1 to 9, but become more noticeable in the fourth instar. The mesothorax has two dark brown, elongated, mid-ventral sclerites positioned anteriorly. Brown, curved sclerites can be seen anterior to the larvapods.

Fourth-Instar Larva. Markings that developed during the third instar become darker brown and much more noticeable; otherwise, the fourth instar is similar to the third. Light brown "lateral spots" begin to appear in the fourth instar; however, they are much more noticeable in the fifth.

Fifth-Instar Larva. The penultimate instar is about 8 mm in length (Figs. 5,6,7). The integument appears somewhat granular dorsally. The larva still tapers caudad but this is much less noticeable than in the earlier instars. Dark brown spotting on the white body is quite noticeable and distinctive. A goblet-shaped light area is noticeable on the dark, prothoracic shield and continues onto the head (Fig. 5). In addition to the distinctly brown sclerites possessed by the previous instar, the fifth has small, dark brown, irregular spots situated laterally on the meso- and metathorax. The yellowish prothoracic sterna are dark antero-laterally but only slightly dark posteriorly. There are three, sometimes four, brown spots arranged laterally on the mesothorax and two to three on the metathorax. Dorso-posterior to the brown, winged spiracles on abdominal segments 1 to 7 are brown spots. Similar spots are evident in the subspiracular area on abdominal segments 2 to 8. In the surpedal area brown spots are present on abdominal segments 1 to 9. Any one of these types of lateral spots may be less noticeable on abdominal segments 1 or 8 (Fig. 6).

Fifth-instar larvae usually remain in the mine until after the final moult. However, they will leave the mine before the moult if the leaves become dry, as they often do when leaves are picked for rearing, or if the leaf tissue has been largely consumed (as was observed by Ripper (1931) for *S. betulae*).

Sixth-Instar Larva. The ultimate instar is white to yellow, with no dark sclerites or markings, and has a hypognathous head.

Parasites

Collections of parasites were made during the first and third weeks of June, 1986. Approximately 150 eggs were screened for parasites, but none was found. However, three species of Chalcidoid parasites were observed and reared from dead larvae in the mines: *Chrysocharis laricinellae* (Ratz.) (2 specimens), *Pnigalio minio* (Walker) (3 specimens), and *Zagrammosoma multilineatum* (Ashmead) (Hymenoptera: Eulophidae) (4 specimens), (Sault Ste. Marie FIDS insect collection, FIDS no. 865-0825). The rate of parasitism was 12%.

Larval Identification

In Lindquist's (1959) key to the larvae of leafmining sawflies on birch in Ontario, the larva of *S. betuleti* falls in the first part of couplet 1 with *F. pusilla* and is distinguished by its dark, segmented thoracic legs; by the presence of dark, curved sclerites anterior to the larvapods; and by the dark ring around the joined anal legs (Fig. 7). Smith (1971) also provides keys to leafmining larvae of birch and oak (*Quercus* spp.), in which *S. betuleti* falls into the first part of couplet 3 of the *Betula* key. The miner is distinguishable from *M. nana* by the presence of dark lateral spots and a goblet-shaped light area on the dark prothoracic shield and head (Figs. 5 and 6).

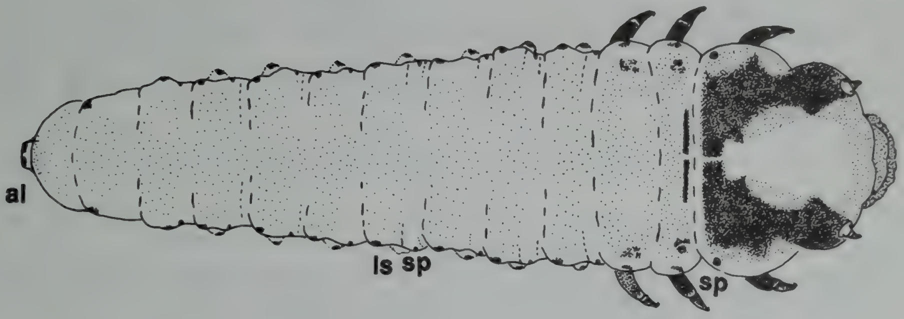

FIGURE 5. The 5th-instar stage: dorsal view. Abbreviations: al=anal leg, ls-lateral spots, sp=spiracle.

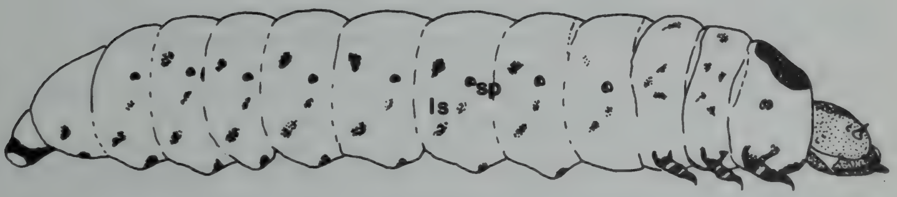

FIGURE 6. The 5th-instar stage: lateral view. Abbreviations: ls=lateral spots, sp=spiracle.

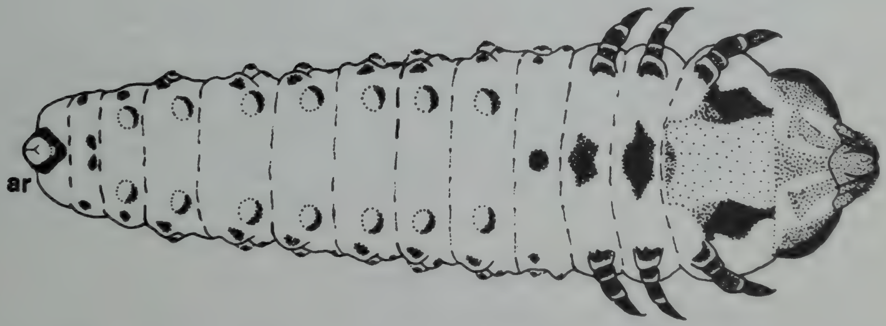

FIGURE 7. The 5th-instar stage: ventral view. Abbreviations: ar=anal ring.

Acknowledgements

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References

Benson, R.B. 1952. Handbooks for the identification of British insects. Vol. VI Part 2(b). Royal Entomological Society. London. 86 pp.

DeClerck, R.A. and J.D. Shorthouse. 1985. Tissue preference and damage by *Fenusa pusilla* and *Messa nana* (Hymenoptera: Tenthredinidae), leaf-mining sawflies on white birch (*Betula papyrifera*). Canadian Entomologist, 117:351-362.

Evans, H.J., R.J. Sajan and H. Brodersen. 1985. Results of forest insect and disease surveys in the Central Region of Ontario. 1984. Government of Canada, Canadian Forestry Service, Sault Ste. Marie, Ont. Miscellaneous Report 22. 35 pp.

*Hering, E.M. 1957. Bestimmungstabellen der Blattminen von Europa. Bk. 1. Uitgeverij Dr. W. Junk,'s-Gravenhage. 648 pp.

Lindquist, O.H. 1959. A key to the larvae of leafmining sawflies on birch in Ontario with notes on their biology. Canadian Entomologist, 91:625-627.

Lindquist, O.H. and M. Thomson. 1970. The biology of a birch leafminer, *Messa nana* (Hymenoptera: Tenthredinidae), new to Canada. Canadian Entomologist, 102:108-111.

*Lorenz, H. and M. Kraus. 1957. Die Larvalsystematik der Blattwespen (Tenthredinoidea und Megalodontoidea). Akademie-Verlag, Berlin. 135 pp.

*Ripper, W.E. 1931. Uber blattminierende Tenthrediniden-Larven an Birken. Zeitschrift für Pflanzenkrankheiten (Pflanzenpathologie) und Pflanzenschutz, 41:182-191.

Smith, D.R. 1971. Nearctic sawflies III. Heterarthrinae: adults and larvae (Hymenoptera: Tenthredinidae). United States Department of Agriculture. Agricultural Research Service. Technical Bulletin 420, Washington, D.C. 84 pp.

Tuomi, J., P. Niemela, and R. Mannila. 1980. Leaves as islands: interactions of *S. betuleti* (Hymenoptera) miners in birch leaves. Oikos, 37:146-152.

Zombori, L. 1978. New sawfly species in the Hungarian fauna (Hymenoptera: Symphyta), IV. Analles Historico-Naturales Musei Nationalis Hungarici, 70:259-264.

*English translation seen

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EFFECT OF PESTICIDES ON PARASITISM OF ARTIFICIALLY DISTRIBUTED EGGS OF THE CODLING MOTH, *CYDIA POMONELLA* (LEPIDOPTERA: TORTRICIDAE) BY *TRICHOGRAMMA* SPP. (HYMENOPTERA: TRICHOGRAMMATIDAE)

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Abstract

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The insecticides, azinphosmethyl (Guthion 25% w.p., 0.70 kg a.i./ha), diflubenzuron (Dimilin 25% w.p., 0.18 kg a.i./ha), permethrin (Ambush 25% w.p., 0.05 kg a.i./ha), and methomyl (Lannate L 0.16 kg a.i./ha), reduced significantly the levels of parasitism of eggs of the codling moth, *Cydia pomonella* (L.), by *Trichogramma minutum* Riley and *T. pretiosum* Riley. At a lower rate of diflubenzuron (Dimilin 25% w.p., 0.06 kg a.i./ha) and at two rates of triflumuron (Alysystin 480F 1.00 and 0.41 kg a.i./ha) levels of parasitism were not affected.

The acaricide, cyhexatin, (Plictran 50 W, 0.56 kg a.i./ha), was also toxic to the *Trichogramma* spp., but the fungicides, captan (Captan 50% w.p., 3.38 kg a.i./ha), dodine (Cyprex 50% w.p., 1.12 kg a.i./ha) and polyram (Polyram 80W, 5.40 kg a.i./ha) did not affect levels of parasitism.

The codling moth, *Cydia pomonella* (L.), is a major pest of apple in most regions of the world where this crop is grown (Putman 1963). In Ontario, *C. pomonella* has one and a partial 2nd generation, and at least two insecticide sprays are applied each season for its control. All of the insecticides used to control this pest have a broad spectrum of activity and are toxic to many non-target organisms, including several parasites and predators. This is of concern especially in the first generation, because insecticides are applied for control of 1st-instar larvae in mid- to late June when several beneficial species are active (Hagley unpublished). Use of a biological agent at this time would eliminate the adverse effects of pesticides on non-target organisms and reduce other adverse environmental effects.

Two species of *Trichogramma* (*T. pretiosum* Riley and *T. minutum* Riley) were recovered from eggs of *C. pomonella* in both unsprayed (no insecticides) and sprayed apple orchards in Ontario (Yu *et al.* 1984; Hagley 1986), and it was felt that augmentation of natural populations of these species might increase their effectiveness against *C. pomonella* in managed orchards. Accordingly, *T. minutum* was released at regular intervals into plots of apple in which few pesticides were applied for pest control to determine the effect of the materials on the efficacy of the parasites.

Materials and Methods

Studies were undertaken in a 2-ha apple orchard at Jordan Station, Ontario. The orchard was comprised of 11-year-old (1982) McIntosh apple trees on MM106 rootstock with cv. Scotia Gold planted every 4th row as a pollinizer. The trees were planted 4.9 x

7.3 m, were ca. 4 m high and had a canopy containing ca. 26,000 leaves in July, 1984 (unpublished data). The orchard was divided into 12 plots ca. 0.17 ha, each containing 30 trees in 1982, and into 16 plots ca 0.10 ha, each containing 18 trees in 1984 and 1985. In 1984 and 1985, each plot was bordered by 1 tree-row in the north-south direction and by two tree-rows in the east-west direction.

Pesticide Applications

In 1982, the effect of 3 fungicides and 2 insecticides on parasitism of eggs of the codling moth by native *Trichogramma* spp. was assessed (Table I). The fungicide, captafol, was applied to all plots (designated A-L) on 26 April for control of apple scab, *Venturia inequalis* (Cooke) Winter. On 10 August sprays of captan were applied to six plots (B,C,E,F,G,H), and sprays of dodine and polyram were each applied to two plots, i.e. plots A and D, and I and J, respectively. The insecticide, permethrin was applied pre-bloom to all plots (A-L) on 5 May for control of the spotted tentiform leafminer, *Phyllonorycter blancardella* (Fabr.) (Lepidoptera: Gracillariidae). Permethrin was re-applied to eight (A-H) of the twelve plots on 9 July and to two captan-treated plots (F,H) on 10 August. Methomyl was also applied to two captan-treated plots (B,C) on 10 August. The remaining two plots (K,L) were used as controls.

TABLE I. Dates of pesticide applications in the study orchard at Jordan Station, Ontario in 1982.

Date	Pesticide and rate (kg a.i./ha) applied	Plots treated[1]
26 April	Captafol (Difolatan 4.8 F 1.09)	A-L
5 May	Permethrin (ambush 25% w.p. 0.05)	A-L
9 July	Permethrin (ambush 25% w.p. 0.05,.10)	A-D(.05),E-H(.10)
10 August	Permethrin (ambush 25% w.p. 0.05)	F,H
	Methomyl (Lannate L 0.16)	B,C
	Captan (Captan 50% w.p. 3.38)	B,C,E,F,G,H
	Dodine (Cyprex 30% w.p. 1.12)	A,D
	Polyram (Polyram 80W, 5.40)	I,J
	Control	K,L

[1] Thirty trees per plot

In 1984 and 1985, applications of azinphosmethyl, diflubenzuron, permethrin, and triflumuron were made to the experimental plots primarily for control of *P. blancardella*, *C. pomonella* , the oblique-banded leafroller, *Choristoneura rosaceana* (Harris) (Lepidoptera: Tortricidae), the apple maggot, *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae), and the plum curculio, *Conotrachelus nenuphar* Herbst. (Coleoptera: Curculionidae). The insecticide treatments were assigned to plots (designated A-P) in randomized block design, and the dates of application and rates used in 1984 and 1985 are given in Table II. Permethrin was applied to one set of four plots (C,E,I,O) pre-bloom, and azinphosmethyl was applied to the same plots post-bloom. Diflubenzuron and triflumuron were each applied to another set of four plots (D,H,J,N and B,F,L,P, respectively) pre- and post-bloom, and the remaining four plots (A,G,K,M) were used as controls. The insecticides were applied to the same plots in 1984 and 1985.

TABLE II. Dates of pesticide applications and releases of *T. minutum* in the study orchard at Jordan Station, Ontario in 1984 and 1985[1,2].

Date	Pesticide and rate (kg a.i./ha) applied	Plots treated[3]	No. *T. minutum* per release tree
1984:			
28 June			20,000 (16)[4]
7 July	Captan (Captan 50% w.p. 3.38)	A-P	21,000 (16)
11 July			21,000 (12)
17 July	Cyhexatin (Plictran 50W, 0.56)	A-P	
18 July			21,300 (8)
24 July			23,130 (8)
1 August			20,600 (8)
8 August	Azinphosmethyl (Guthion 50% w.p. 0.70) Diflubenzuron (Dimilin 25% w.p. 0.18) Triflumuron (Alsystin 480F, 1.00)	C,E,I,O D,H,J,N B,F,L,P	
9 August			17,700 (8)
15 August			15,540 (8)
1985:			
29 May			35,714 (9)[5]
3 June	Azinphosmethyl (Guthion 50% w.p., 0.70)	C,E,I,O	
7 June			33,334
13 June	Polyram (Polyram 80W, 5.40)	A-P	
17 June			33,334
19 June			33,334
21 June	Azinphosmethyl (Guthion 50% w.p., 0.70)	C,E,I,O	
26 June			33,334
4 July			35,714
8 July	Phosalone (Zolone 30% w.p., 1.0)	A-E,H,I,L-P	
9 July	Captan (Captan 50% w.p. 3.38)	A-P	
11 July			31,334
26 July	Cyhexatin (Plictran 50W, 0.56)	A-P	
30 July			31,334
1 August	Azinphosmethyl (Guthion 50% w.p., 0.70) Diflubenzuron (Dimilin 25% w.p., 0.06) Triflumuron (Alsystin 480F, 0.41)	C,E,I,O D,H,J,N B,F,L,P	
8 August			35,714

[1] In 1984 Superior oil (60-70 vis. 65L) applied on 4 April, polyram (Polyram 80 W, 5.40 kg a.i./ha) on 5 and 10 May, and captan at the above rate on 14 June to all plots, A-P; diflubenzuron (plots D,H,J,N) and triflumuron (plots B,F,L,P) at the above rates on 14 May and 6 June; permethrin (plots C,E,I,O) (Ambush 25% w.p., .05 kg a.i./ha) on 14 May and azinphosmethyl at the above rate on 11 June to the same plots.

[2] In 1985 Superior oil (60-70 vis, 65L) applied on 18 April and polyram at the above rate on 26 April, 6 and 21 May to all plots, A-P; diflubenzuron (plots D,H,J,N) and triflumuron (plots B,F,L,P) at the above rates on 2 and 24 May; permethrin (plots C,E,I,O) (Ambush 25% w.p., .04 kg a.i./ha) on 8 May.

[3] Eighteen trees per plot.

[4] Number of trees on which releases were made (release trees).

[5] Nine trees were used for each release.

The European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae), was controlled with one summer application of cyhexatin made to all plots including the controls on 17 July, 1984, and on 26 July, 1985 (Table II). Also, on 8 July, 1985, a border spray (2-3 tree rows deep around the edge of the orchard) of phosalone, which is of low toxicity to *T.*

minutum (Yu *et al.* 1984), was applied to control immigrating adults of the apple maggot, *R. pomonella* (Table II). This spray was applied to the border rows of three of the four replicated plots of each treatment.

In both 1984 and 1985 apple scab was controlled in all plots with sprays of captan and polyram (Table II), at the rates used in 1982.

All pesticides were applied with a Swanson hydraulic sprayer delivering 630 L/ha at 1380 k/Pa pressure.

Trichogramma Rearing Method

Trichogramma minutum were obtained from codling moth eggs in an abandoned orchard at Vineland, Ontario, during 1979 and 1980. The parasites were maintained initially on eggs of the Mediterranean flour moth (MFM), *Anagasta kuhniella* (Zeller) (Lepidoptera: Pyralidae), which were reared on rolled oats in cardboard trays in a system similar to that of Daumal *et al.* (1975). In 1983, the factitious host for rearing *T. minutum* was switched from MFM to the Angoumois grain moth (AGM), *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). The AGM were reared on grains of wheat in cribs at 25 ± 2°C, 75 ± 10% R.H. and 16hL:8hD. Eggs of AGM, parasitized by *Trichogramma*, were held for varying proportions of time at 25°C, 16hL;8hD and 17°C, 0hL:24hD to program the parasites to emerge within 24 hours after their release (i.e. exposure to light and warm temperatures) (Laing and Eden, submitted).

Releases of Trichogramma minutum

In 1984 releases of *T. minutum* were made by cutting plasticised cards (7.5 x 12.5 cm) containing parasitized eggs of AGM into sections containing ca. 10,000 female parasites. These sections were placed in small waxed paper cups, the open end of which was covered with saran mesh to prevent entry of predators while allowing the parasites to escape. The cups were suspended with wire twisters from twigs ca. 1.5 m above ground level just within the tree canopy. In 1985, the sections of cards containing the parasitized egg were folded along the centre. A piece of wire inserted in the centre along the folded edge enabled the card to be hung in the tree canopy and shielded the parasites from direct sunlight and inclement weather. This method greatly reduced the handling time used in distributing the parasitized eggs and also the likelihood of damaging the parasites prior to release. Releases were made to coincide with the oviposition period of *C. pomonella* as determined by the examination of leaf samples (100 leaves twice/wk) taken at random throughout the orchard and by heat unit summations (Hagley *et al.* 1978).

In 1984 parasitized eggs were distributed on 8 or 16 trees per plot at intervals of 6-9 d commencing on 28 June (Table II). Release trees were randomly chosen in different rows on each date that releases were made so that parasites were distributed throughout the orchard during the test period. From 15,540 to 23,130 eggs were placed on each release tree for a total of ca. 2,700,000 eggs in 8 releases between 28 June and 15 August. In 1985, parasitized eggs were distributed on each of 9 release trees during each release for a total of ca. 2,500,000 eggs in 8 releases at intervals of 2-19 d between 29 May and 8 August (Table II). The same release trees were used for all releases of *T. minutum*.

Monitoring activity and dispersal of trichogramma

Dispersal of *Trichogramma* from release sites and levels of natural parasitism by *Trichogramma* were monitored using egg cards. Sections of waxed paper cages containing 40, 24-48hr old eggs of *C. pomonella* or of the oriental fruitmoth, *Grapholitha molesta* (Busck.) (Lepidoptera: Tortricidae), were glued to 7.5 x 12.5 cm white index cards. The cards were stapled to twigs ca. 1.5 m above ground level just within the tree canopy and collected after 5 days. The cards were then placed in 25 cm diameter petri dishes in the laboratory at 20-22°C for parasite development. Those eggs that turned black were removed on small pieces of the card and placed in stoppered glass vials (6.5 cm l x 1.6 cm diam) for adult emergence. In all years egg cards were deployed on trees in the centre row of each plot and in 1984 they were also deployed on the unsprayed buffer trees surrounding the treated plots. The total number of eggs used per plot per exposure was 640 in 1982 (12 August - 9 September), 283-383 in 1984 (5 July - 23 August), and 320-356 in 1985 (27 May - 20 August).

Data on per cent parasitism (arcsine transformation) and on the number of *Trichogramma* emerging per host egg (log X + 1 transformation) were analyzed using ANOVA and means separated by Duncan's multiple range test. Data on the effects of cyhexatin on levels of parasitism were analyzed by Student's "t" tests.

Results and Discussion

In 1982, the fungicides captan, dodine, and polyram did not affect significantly ($P>0.05$) parasitism of eggs of *C. pomonella* by naturally occurring *Trichogramma* sp., probably *T. pretiosum* Riley (cf. Hagley 1986) Table III). Captan and polyram were reported to have low toxicity to *T. cacoeciae* Marchal (Franz *et al.* 1976, Hassan 1983). Accordingly, these fungicides were used to control apple scab in the test plots during 1984 and 1985.

TABLE III. Effect of fungicides and insecticides on percent parasitism of eggs of *C. pomonella* by naturally occurring *Trichogramma* spp. in 1982[1,2].

Treatment	% Parasitism
Control[3]	33.5±12.6 a[4]
Captan	26.9±11.1 a
Dodine	25.5± 9.6 a
Polyram	30.5±14.2 a
Captan + Permethrin	14.8±10.2 b
Captan + Methomyl	12.6± 7.2 b

[1] A total of 3200 eggs observed per treatment on 5 sample dates, viz. 12, 19, 25 August and 2 and 9 September. Data pooled for analysis.

[2] Insecticides applied on dates and rates shown in Table I.

[3] On 5 August mean percent parasitism on 16 cards in the control plots was 57.5±5.4, and in the plots sprayed with permethrin on 9 July, 62.6±5.0.

[4] Means ± SE followed by the same letter not significantly different ($P=0.05$).

Application of permethrin and methomyl to captan-treated plots reduced significantly ($P<0.05$) the proportion of eggs that were parasitized (Table III). Amayan (1982) reported, however, that releases of *T. pretiosum* could be made 48 h after application of methomyl.

In 1984, levels of parasitism in eggs exposed between 7 and 26 July, i.e. post-application of diflubenzuron and triflumuron on 6 June and azinphosmethyl on 11 June were not affected by any treatment (Table IV). However, in August, when eggs were placed on trees 3-8 d post-application of diflubenzuron (0.18 kg a.i./ha), i.e. between 11 and 16 August, parasitism was significantly reduced. In 1985, diflubenzuron (0.06 kg a.i./ha) was applied on 1 August, and would have contacted eggs set out on 30 July and adults emerging from these eggs, as well as those emerging from eggs set out on 8 August. However, levels of parasitism were not affected significantly 1 to 5 d post-application of the insecticide

(Table IV). Marshall *et al.* (1988) have shown that residues of diflubenzuron are present on apple foliage up to 19 wk post-application and the insecticide at the higher rate used in 1984 might have affected survival of adult parasites emerging from host eggs set out on 9 and 15 August. In laboratory studies, Brown and Respicio (1981) reported increased mortality of adults of the egg parasitoid, *Oencyrtus kuvanae* (Howard) (Hymenoptera: Encyrtidae) with increasing concentrations of diflubenzuron, and House *et al.* (1980) reported that the insecticide did not affect levels of parasitism of the eggs of *Heliothis* spp. by *T. pretiosum* when applied at a rate of 70 g a.i./ha.

TABLE IV. Percent parasitism of eggs of *C. pomonella* by *T. minutum* in plots treated with insecticides during 1984 and 1985[1].

		% parasitism ± S.E.			
Period eggs exposed	Total no. eggs/ treatment	Control (A,G,K,M)[2]	Diflubenzuron (D,H,J,N)	Permethrin + Azinphosmethyl (C,E,I,O)	Triflumuron (B,F,L,P)
1984:					
7-12 July	283-350	50.4±13.2a[3]	33.4± 8.8a	37.0± 6.0a	43.6±12.7a
21-26 July	313-352	22.0± 9.3b	9.4± 7.9b	14.8± 9.1b	23.2± 8.8b
28 July - 2 August	322-365[4]	14.8± 7.4	22.2±14.4	19.8±15.7	17.6±14.5
11-16 August	366-383	23.6± 6.1d	3.2± 3.2e	2.6± 2.6e	12.8± 7.6de
1985:					
5-10 June	320	7.9± 4.8a	5.0± 4.2a	2.3± 2.3a	15.1± 7.8a
27 June - 2 July	320	14.7± 5.3b	9.4± 4.1b	23.8± 8.8b	20.7± 8.3b
18-23 July	480-573	97.8± 2.3c	83.5± 7.1c	54.5±24.4c	74.8±13.4c
2-6 August	320-356	33.8±19.5d	26.5±19.7d	0.0± 0.0[5]	29.7±19.7d
8-12 August	320-344	53.8±17.8e	21.4±13.6e	3.8± 2.9f	25.1±10.3e

[1] Insecticides applied on dates and at rates shown in Table II.

[2] Experimental plots.

[3] Means ± SE for each date followed by the same letter not significantly different ($P=0.05$).

[4] In each treatment, including the control, parasitism occurred on only 20% of the cards set out and data were not analyzed statistically.

[5] Not included in statistical analysis.

Parasitism was also reduced significantly in the permethrin + azinphosmethyl treated plots in August 1984 when eggs were placed in the orchard from 11 to 16 August, 3 to 5 d post-application of azinphosmethyl on 8 August (Table IV). In 1985, no parasitism occurred when egg cards were set out from 2 to 6 August, 1 to 5 d post-application of azinphosmethyl, and levels of parasitism were significantly reduced on cards set out on 8 to 12 August, 7 to 11 d post-application of the insecticide (Table IV). Although permethrin was reported to be toxic to *T. pretiosum* (Bull and House 1983, Jacobs *et al.* 1984), and disruptive to parasitism by *T. minutum* for 16 d (Yu *et al.* 1984), this insecticide was applied once in the pre-bloom period on 14 May in 1984, and on 8 May, in 1985, and likely had little, if any, effect on the levels of parasitism observed. The significant reductions in parasitism following application of azinphosmethyl probably reflects the toxicity of residues of this insecticide to emerging adult *T. minutum* (cf. Yu *et al.* 1984) in 1984 and 1985, and to host eggs (cf Hagley 1975, Pree and Hagley 1977) set out on 30 July 1985, one day prior to application of the insecticide.

The toxicity of azinphosmethyl to adult *Trichogramma*, as well as to host eggs, probably also resulted in the reduction in the number of parasites recovered from each host egg on cards exposed in treated plots (Table V). Azinphosmethyl might also have killed the parasite in the early stages of its development within the host egg, as reported by Gloria (1978) for *Aphelinus mali* (Hald) (Hymenoptera: Encyritidae), an endoparasite of the woolly apple aphid, *Eriosoma lanigerum* (Haus.) (Homoptera: Aphididae). Emergence of parasites from host eggs exposed in diflubenzuron and triflumuron plots was not affected significantly. Brown and Respicio (1981) reported that progeny production in the egg parasite, *O. kuvanae*, was not affected by topical application of diflubenzuron to eggs of its host, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae).

TABLE V. Effect of insecticides[1] on the number of *Trichogramma* spp. emerging per host egg on cards exposed in the experimental plots in the study orchard at Jordan Station, Ontario, in 1985.

Treatment	No. Eggs Observed	No. *Trichogramma* per egg (Mean ± SE)
Control	1221	0.91±0.09a[2]
Diflubenzuron	822	0.71±0.13ab
Triflumuron	786	0.76±0.06ab
Permethrin + Azinphosmethyl	617	0.53±0.09b

[1] Insecticides applied on dates and at rates shown in Table II.

[2] Means ± SE followed by the same letter not significantly different (P=0.05).

In both 1984 and 1985, there was a significant reduction in levels of parasitism by *Trichogramma* spp. following the application of cyhexatin on 17 and 26 July, respectively, to the entire orchard for control of *P. ulmi*. In 1984, the mean level of parasitism in all plots was reduced from 41.4±5% (SE) on 20 cards set out from 7-12 July to 1.8% on 20 cards set out from 14-19 July. During the latter period, when the eggs were exposed to plictran applied on 17 July, parasitism occurred on only 2 of the 20 cards compared with 18 of the 20 cards exposed on 7-12 July. Thereafter, in both sprayed and control plots parasitism remained low, and occurred on 20% of the cards set out during the period 28 July to 2 August (Table IV).

In 1985, the level of parasitism on 16 cards randomly deployed throughout the orchard was reduced from 77.6±7.6(SE)% on 23 July to 23.2±9.7(SE)% on 30 July ($t=4.31$, $P<0.001$), 4 d post-application of cyhexatin on 26 July. Franz *et al.* (1980) reported that kelthane, carzol and morestan were highly toxic to *T. cacoeciae* Marchal, while fenbutatin oxide (Torque) was of low toxicity. Although recommended for mite control in Ontario, the acceptance of these acaricides as alternatives to cyhexatin would be influenced by their toxicity to *T. pretiosum* and *T. minutum* if these parasites are to be used in inundative releases.

Failure to obtain higher levels of parasitism after mass-release of *T. minutum* might have resulted from the release of too few parasites and/or the use of too few release sites. In studies with *T. cacoeciae* and *T. minutum* in a 0.4 h fifty-tree block of semi-dwarf apple trees, Dolphin *et al.* (1972) estimated that on trees with ca. 16,000 leaves, releases of more than 1,000 parasites per tree per wk would be required to give control of *C. pomonella*. Voegelé *et al.* (1979) also reported that when *Trichogramma* sp. was released at 120 points in a 1 ha plot, parasitism increased from 5.64% on 18-22 June to 66.25% on 12 August. The number of release sites used per 0.1 ha plot in the present study varied between 8 and 16 per wk in 1984, and were 9 per wk in 1985, and the number of leaves per tree was ca 26,000 (unpublished data). A larger number of sites would probably be needed, therefore, to increase significantly levels of parasitism in the experimental plots. Also, in 1985, when releases were made over a longer period of time, mean levels of parasitism in the control plots peaked in the third week of July, and remained higher after this period than earlier in June and July. These data suggest that releases of larger numbers of parasites early in the season might result in greater parasitism later in the season. However, peak levels of parasitism in both 1984 and 1985 also coincided with peak activity of naturally occurring *Trichogramma* sp (cf. Hagley 1986), and these parasites undoubtedly contributed to the high levels of parasitism observed.

In summary, our data show that several pesticides currently used for pest control in commercial apple orchards adversely affect parasitism of eggs of the codling moth by *T. minutum*, and continued use of these materials will reduce the potential of this parasite for control of *C. pomonella*.

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References

Amayan, M. 1982. Efecto de algunos insecticidas sobre la accion parasitica del *Trichogramma pretiosum* (Riley) (Hymenoptera: Trichogrammatidae) liberados despues de las applicaciones. *In* Les Trichogrammes Ier Symposium International Antibes, 20-23 Avril, Paris. (Cited in Review of Applied Entomology, 71:(1983):554.

Brown, M.W. and N.C. Respicio. 1981. Effect of diflubenzuron on the gypsy moth egg parasite *Oencyrtus kuvanae* (Hymenoptera: Encyrtidae). Melsheimer Entomological Series No. 31. pp. 1-7.

Bull, D.L. and V.S. House. 1983. Effects of different insecticides on parasitism of host eggs by *Trichogramma pretiosum* Riley. Southwestern Entomologist, 8:46-53.

Daumal, J., J. Voegelé and P. Brun. 1975. Les Trichogrammes II. Unite de production massive et quotidienne d'un hôte de substitution *Ephestia kuchniella* Zell (Lepidoptera, Pyralidae). Annales de Zoologie, Ecologie Animale, 7:45-59.

Dolphin, R.E., M.L. Cleveland, T.E. Mouzin and R.K. Morrison. 1972. Release of *Trichogramma minutum* and *T. cacoeciae* in an apple orchard and the effect on populations of codling moths. Environmental Entomology, 1:481-484.

Franz, J.M., S.A. Hassan and H. Bogenschutz. 1976. Some results of standardised laboratory tests on the effects of pesticides on beneficial entomophagous arthropods. Nachrichtenblatt des Deutschen Pflanzenschutzdienstes, 28:181-183.

Franz, J.M., H. Bogenschutz, S.A. Hassan, P. Huang, E. Naton, H. Suter and G. Viggiani. 1980. Results of a joint pesticides test programme by the Working Group. Pesticides and Beneficial Arthropods. Entomophaga, 25:231-236.

Gloria, B.R. 1978. Chemical control of the woolly aphid *Eriosoma lanigerum* (Haus.) on apple. Revista Peruance de Entomologia, 21:118-120 (Cited in Review of Applied Entomology, 70(1982):490.

Hagley, E.A.C. 1975. Note on the ovicidal effect of three insecticides against the codling moth (Lepidoptera: Olethreutidae). Proceedings of the Entomological Society of Ontario, 108:69-77.

Hagley, E.A.C. 1986. Occurrence of *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) in apple orchards in southern Ontario. Proceeding of the Entomological Society of Ontario, 117:79-82.

Hagley, E.A.C., R. Trottier, D.H.C. Herne, A. Hikichi and A. Maitland. 1978. Pest Management in Ontario apple orchards. Catalogue No. A52-50/1978, Ministry of Supply and Services, Canada.

Hassan, S.A. 1983. Ergebnisse der Laborprufung einer Reiche von Pflanzenschutzmitteln auf Eiparasiten der Gattung *Trichogramma* (Hymenoptera: Trichogrammatidae). Nachrichtenblatt des Deutschen Pflanzenschutzdienstes, 35:21-25.

House, V.S., J.R. Albis, R.K. Morrison and D.L. Bull. 1980. Effect of diflubenzuron formulations on the egg parasite *Trichogramma pretiosum*. Southwestern Entomologist, 5:133-138.

Jacobs, R.J., C.A. Kouskolekas and H.R. Gross, Jr. 1984. Responses of *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae) to residues of permethrin and endosulfan. Environmental Entomology, 13:355-358.

Laing, J.E. and G.M. Eden. Mass production of the egg parasite *Trichogramma minutum* (submitted, Memoirs of the Entomological Society of Canada).

Marshall, D.B., D.J. Pree and B.D. McGarvey. 1988. Effects of benzoylphenylurea insect growth regulators on eggs and larvae of the spotted tentiform leafminer, *Phyllonorycter blancardella* (Fabr.) (Lepidoptera: Gracillariidae). Canadian Entomologist, 120:49-62.

Pree, D.J. and E.A.G. Hagley. 1977. Toxicity of some insecticides to eggs of the oriental fruit moth and codling moth. Proceedings of the Entomological Society of Ontario, 108:69-77.

Putman, W. 1963. The codling moth, *Carpocapsa pomonella* (Lepidoptera: Tortricidae): A review with special reference to Ontario. Proceedings of the Entomological Society of Ontario, 93(1962):22-60.

Voegelé, J., D. Martouret and R. Goujet. 1979. Preliminary experiments using *Trichogramma* sp. against the codling moth in apple orchards in the Parisian region. Mittleilungen aus der Biologischen Bundesanstalt fur Land- und Forstwirtschaft Berlin-Dahlem (1978) No. 180, 120 pp. (Cited in Review of Applied Entomology, 67(1979):345.

Yu, D.S.K., E.A.C. Hagley and J.E. Laing. 1984. Biology of *Trichogramma minutum* (Riley) collected from apples in southern Ontario. Environmental Entomology, 13:1324-1329.

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REPRODUCTIVE BIOLOGY OF *HOLCOTHORAX TESTACEIPES* (HYMENOPTERA: ENCYRTIDAE) AND ITS EFFECT ON DEVELOPMENT OF THE HOST, *PHYLLONORYCTER BLANCARDELLA* (LEPIDOPTERA: GRACILLARIIDAE)

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Abstract *Proc. ent. Soc. Ont.* 120:35-41 (1989)

Holcothorax testaceipes (Ratzeburg) was pro-ovigenic and had a potential fecundity of 25 eggs per female. When provided with excess host larvae, female parasitoids produced a mean number of 9.1 + 3.4 broods each containing about 12 progeny in an average lifespan of 7.5 + 2.7 days.

Newly-oviposited and five-day-old eggs of *Phyllonorycter blancardella* (F.) were parasitized by *H. testaceipes*. However, survival of the parasitoids was greater when they were reared in newly-oviposited eggs than in older host eggs. At 25°C the parasitoid completed development in 35 to 37 days regardless of the age of the host at the time of oviposition.

Larval *P. blancardella* parasitized by *H. testaceipes* exhibited delayed development and developed larger head capsules than non-parasitized larvae. The increased feeding period and resulting larger size of parasitized hosts could have serious implications for biological control if *P. blancardella* were not an indirect pest of apples.

Holcothorax testaceipes (Ratzeburg) is a polyembryonic, egg-larval parasitoid of the apple leafminer, *Phyllonorycter ringoniella* Matsumura in Japan (Tachikawa 1966; Sekita and Yamada 1979). This parasitoid was introduced from Japan and released in southern Ontario in 1983 (Laing, unpublished data) to complement the natural enemies of the spotted tentiform leafminer (STLM), *Phyllonorycter blancardella* (F.), a serious introduced pest that undergoes three generations per year on apple in eastern North America (Pottinger and LeRoux 1971; Johnson et al. 1976; Dutcher and Howitt 1978; Weires et al. 1980; Maier 1984; Ridgway and Mahr 1985). Tachikawa (1966) noted that *H. testaceipes* was an important polyembryonic parasitoid of *P. ringoniella* in Japan, but he provided no detailed information regarding the biology of this parasitoid.

The goals of this study were to determine the fecundity of *H. testaceipes* and age of STLM eggs successfully parasitized in order to evaluate the potential of this parasitoid as a biological control agent and to investigate the effect of parasitism by *H. testaceipes* on the growth and development of STLM.

Materials and Methods

Stock cultures of *H. testaceipes* were established using parasitoids on *P. ringoniella* received as overwintering pupae from Japan. The pupae were maintained in diapause from November to April in the dark at 2 ± 1°C and 75% RH, then adults were allowed to emerge by placing the cocoon masses in screen-topped Petri dishes at 25 ± 2°C, 75% RH and 16L:8D. A laboratory colony of STLM was maintained at 25 ± 2°C on apple seedlings to provide a constant source of host eggs. Seedlings infested with STLM eggs were caged for 48 hours with adult *H. testaceipes* in plastic containers (25 x 25 x 25 cm). The parasitized STLM eggs and larvae were maintained at 25 ± 2°C and about 50% RH.

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Fecundity of *H. testaceipes*

Freshly-emerged female *H. testaceipes* were confined with males for either 10 h or 7 days. The mated females subsequently were fixed in Bouin's fixative, embedded in paraffin, sectioned transversally or longitudinally at 7-µm intervals, and stained with Harris' hematoxylin and eosin. The eggs in the ovaries of 15, 10-hour-old and 15, 7-day-old females were counted to estimate the potential fecundity of *H. testaceipes*.

To determine realized fecundity of *H. testaceipes*, 21 female *H. testaceipes* were placed individually in Petri dishes (9 cm diam) with a male for 10h, then confined in a Petri dish at 25°C with an apple leaf containing about 10 host eggs (< 24 h old). After 5 hours, the female was transferred onto another leaf with a second batch of about 10 host eggs. Leaves with parasitized host eggs were held at 25°C for parasitoid development. Females were kept in Petri dishes overnight and provided with a honey solution (25% by volume). This procedure was repeated once a day (about 20 hosts per day) until the death of each female parasitoid. Records were kept of the numbers of hosts parasitized by each of the female parasitoids.

Age of Host Eggs Parasitized

To determine the developmental rate and survival of parasitoids reared from host eggs that had been parasitized at different ages, about 200 newly-emerged adult leafminers were caged on an apple seedling for 24 h and then were removed with the cage. Host eggs on two branches of the seedling were immediately exposed to approximately 500 newly-emerged adult *H. testaceipes* (not sexed) for 24 h at 25 ± 2°C. At the same time, two small sleeve cages were tied over two other STLM-infested branches on the same seedling to prevent parasitism. Host eggs on the two parasitoid-free branches were held at 25 ± 2°C for five days (the average duration of the embryonic stage of *H. testaceipes*, unpublished data), then approximately 500 newly-emerged adult parasitoids were introduced into the two cages for 24 h. Both sets of parasitized STLM eggs were reared at 25 ± 2°C and 75% RH. Time from oviposition to pupation and to adult emergence of the parasitoids was determined, and percent emergence from the two treatments was compared.

Effects of Parasitism on Growth of STLM

To determine if parasitism by *H. testaceipes* caused prolonged development of *P. blancardella*, 100 newly-emerged adult STLM were released into a fine-mesh sleeve cage tied over an apple seedling. The leafminers were replaced on the following day by approximately 500 newly-emerged adult *H. testaceipes* (not sexed). The host eggs were exposed to the parasitoids for 24 h and then the sleeve cage was removed and the apple seedling held in a greenhouse at 25 ± 2°C. For about 20 days after parasitism (until all parasitoids had pupated), the development of parasitoids and hosts was checked daily. Duration of larval feeding and head capsule width of 20 last-instar larvae of both parasitized and non-parasitized hosts was compared.

The time from oviposition until hatching of host eggs was determined by daily observation of 60 fresh, unparasitized host eggs held at 25 ± 2°C. The average duration of embryonic development and percent hatching of unparasitized host eggs were determined. Daily observations in the previous experiment indicated that the parasitoids had no observable impact on the average duration of the embryonic development of STLM. The duration of the embryonic stage, determined in the above test, was used to determine the duration of larval feeding for both parasitized and nonparasitized hosts (the time from egg hatching until pupation). Student's t-test was used to determine if there were significant differences in duration of larval feeding or the size of parasitized and non-parasitized hosts.

Results and Discussion

Fecundity of *H. testaceipes*

The number of eggs in the abdominal sections of 10-hour-old and 7-day-old female parasitoids did not differ (Figs. 1 and 2). Each age class of the sectioned, female *H. testaceipes* had a potential fecundity of about 25 eggs; these were difficult to count accurately. The mean number of eggs oviposited per female for 21 female parasitoids was 9.1 ± 3.4 (realized fecundity) during an average lifespan of 7.5 ± 2.7 days. Females that lived longer tended to lay more eggs. Female *H. testaceipes* had laid more than half the total eggs oviposited by the middle of their adult lifespan, when sufficient hosts were provided.

The difference between potential and realized fecundity may be explained by several factors: 1) cannibalism among sap-feeders (instars I-III) of STLM, as observed by Pottinger and LeRoux (1971), could have inflicted mortality on *H. testaceipes* contained inside host larvae; 2) parasitoids tended to thrust repeatedly with their ovipositor into the same host and showed no reluctance to attack host eggs which had been parasitized by others, which may have resulted in superparasitism and wastage of eggs; 3) about 66% of the unparasitized host eggs were viable, therefore, some host eggs parasitized by *H. testaceipes*, probably did not develop. The incidence of mutilation of host larvae which would kill both the host and internal parasitoids, may have contributed to a lower realized fecundity, although this was not observed directly.

The estimation of realized fecundity would approximate the minimum reproductive capacity of female *H. testaceipes* for the conditions used in our experiment. It is unlikely that female parasitoids could achieve their potential fecundity in the field unless *P. blancardella* was present at very high densities. Since *H. testaceipes* is polyembryonic and produces about 12 progeny per egg laid (= a brood) (Wang and Laing, in press), an average of 9 successful eggs per female would produce about 110 parasitoids. Thus, the parasitoid population would be able to increase rapidly if hosts were available and conditions for parasitism were favorable.

Stoner and Weeks (1976) observed that *Copidosoma truncatellum* (Dalman) parasitized a mean of 21.4 host eggs per female at 25°C whereas the mean number of eggs dissected from the ovaries of freshly emerged females was 44 at 20.2°C and 47.3 at 28.9°C which was more than double the realized fecundity. Like *H. testaceipes*, female *C. truncatellum* emerged as adults with their full complement of eggs (i.e., they were pro-ovigenic).

Age of Host Eggs Parasitized

Both newly-oviposited and five-day-old eggs of STLM were parasitized by *H. testaceipes*, which suggests that eggs of the parasitoid could be deposited and could develop in the host egg at any time during the embryonic period of the host. However, survival of individual parasitoids that reached the pupal stage was greater when they were reared in newly-deposited eggs than in five-day-old host eggs even though there was no significant difference in either the number of broods producing viable adults or the developmental rates of the parasitoid from different-aged host eggs (Table I). At 25°C, the parasitoid completed development within 35 to 39 days, irrespective of the age of the host egg at the time of parasitoid oviposition.

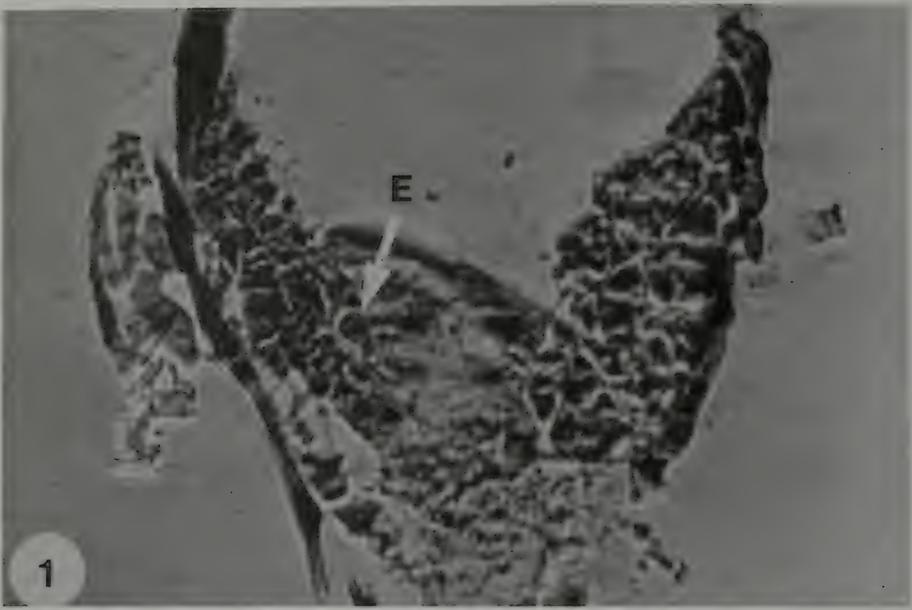

Figure 1. Longitudinal section of the abdomen of a 10-hour-old female *Holcothorax testaceipes* containing mature and well-differentiated eggs (E). x 200

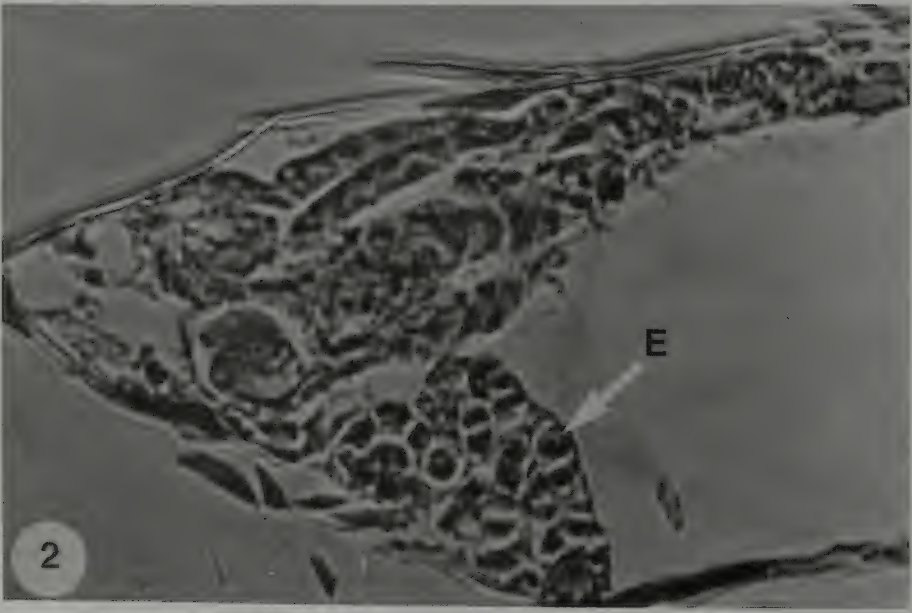

Figure 2. Longitudinal section of the abdomen of a 7-day-old female *Holcothorax testaceipes* containing mature and well-differentiated eggs (E). x 200

TABLE I. Developmental rate and survival of *Holcothorax testaceipes* reared on host eggs of different ages.[1]

Variable measured	From 1-day-old *P. blancardella* eggs	From 5-day-old *P. blancardella* eggs
% viable cocoon masses	84.5 (78) a	76.6 (85) a
% (± S.E.) emergence of adults from hosts	75.9 ± 5.1 (35) a	55.3 ± 5.8 (43) b
Days (± S.E.) to pupate after oviposition	27.4 ± 0.4 (105) a	27.1 ± 0.2 (211) a
Days (± S.E.) to emerge after pupation	9.5 ± 0.04 (524) a	9.6 ± 0.08 (684) a
Duration of emergence (± S.E.)	1.91 ± 0.22 (33) a	1.85 ± 0.19 (34) a

[1]Means in the same row followed by the same letter do not differ significantly at $P<0.05$ (F test). Number in parentheses indicates the number of cocoon masses observed.

The lack of influence of host age at oviposition on development also was reported for the polyembryonic encyrtid *Copidosoma truncatellum* which parasitized host eggs from 1 h to 72 h old (Stoner and Weeks 1976). Jubb and Watson (1971) observed that the developmental time of the egg parasitoid *Telenomus utahensis* Ashmead in either *Chlorochroa sayi* Stal or *C. uhleri* Stal did not change when the age of the host egg varied from less than 1 day to 4 days at the time of parasitoid oviposition.

Effects of Parasitism on Growth of STLM

STLM larvae parasitized by *H. testaceipes* exhibited delayed development and developed larger head capsules compared to nonparasitized larvae (Table II). Prolonged development in the host may have resulted in better synchronization of the emergence of parasitoids and the occurrence of host eggs during the spring generation of STLM when oviposition by the leafminers may be delayed due to low temperatures. Delayed development also could be an adaptation by the parasitoid to utilize fully the host's tissues and attain maximum brood size while larger hosts could be an advantage to parasitoids because the size of the parasitoid would depend, at least partially, on the amount of nutrition provided for each brood by the host.

Fitzgerald and Simeone (1971) observed a similar result in *Paraleurocerus bicoloripes* Girault, a polyembryonic encyrtid parasitoid of *Marmara fraxinicola* Braun, a bark miner of white ash. Parasitized *M. fraxinicola* fed longer in the spring and grew larger than nonparasitized hosts. The authors viewed the ability of *P. bicoloripes* to influence host development as an extension of the general habit of polyembryonic Encyrtidae to maximize brood size by remaining relatively quiescent until the host completes its larval growth. However, this phenomenon is not a generality among all parasitoids. Normal larvae of *Pieris rapae* were found to consume more food than those parasitized by the solitary braconid, *Apanteles rubecula* Marsh, but less than those parasitized by the gregarious parasitoid, *A. glomeratus* (L.) (Rahman 1970). Powers and Oatman (1984) reported that parasitization of the potato tuberworm, *Phthorimaea operculella* (Zeller), by either of the two solitary braconid parasitoids, *Chelonus kellieae* Marsh and *Chelonus phthorimaeae* Gahan, did not affect the duration of development of host larvae and resulted in smaller head capsules, and shorter body length of parasitized fourth-instar hosts. These varied results suggest that gregarious and polyembryonic parasitoids use a different developmental strategy than solitary parasitoids.

TABLE II. Effect of parasitism by *Holcothorax testaceipes* on duration of larval feeding and head capsule width of the last-instar larva of *Phyllonorycter blancardella*.

Observation	No. observations	Mean ± S.E.
Duration of larval feeding (days)		
parasitized	91	23.2 ± 0.2
nonparasitized	76	18.5 ± 0.4
Width of head capsule (mm)		
parasitized	15	0.34 ± 0.004
nonparasitized	26	0.32 ± 0.003

Means for each observation are significantly different at $P<0.05$ (Student's t-test).

Our studies indicate that *H. testaceipes* has a high potential reproductive rate which is a desirable attribute for controlling STLM. Increased size of hosts could cause more damage to host plants, however, the leafminer feeds only on apple foliage and not on the fruit. Since STLM is an indirect pest of apples, its economic threshold will be higher than that of a direct pest of apples. Increased host size might allow development of larger and/or more numerous parasitoids to attack subsequent host generations. *H. testaceipes* oviposits on host eggs of any age which provides a larger window of opportunity for the adult females. This would facilitate synchronization between the parasitoid and its host and our efforts at colonizing the parasitoid in North America.

References

Dutcher, J.D. and A.J. Howitt. 1978. Bionomics and control of *Lithocolletis blancardella* in Michigan. Journal of Economic Entomology, 71:736-738.

Fitzgerald, T.D. and J.B. Simeone. 1971. Polyembryony in *Paraleurocerus bicoloripes* (Hymenoptera: Encyrtidae). Annals of the Entomological Society of America, 64:744-776.

Johnson, E.F., J.E. Laing, and R. Trottier. 1976. The seasonal occurrence of *Lithocolletis blancardella* (Gracillariidae), and its major natural enemies in Ontario apple orchards. Proceedings of the Entomological Society of Ontario, 107:31-45.

Jubb, Jr., G.L. and T.F. Watson. 1971. Development of the egg parasite *Telenomus utahensis* in two pentatomid hosts in relation to temperature and host age. Annals of the Entomological Society of America, 64:202-205.

Maier, C.T. 1984. Seasonal development and flight activity of the spotted tentiform leafminer, *Phyllonorycter blancardella* (Lepidoptera: Gracillariidae), in Connecticut. Canadian Entomologist, 116:435-441.

Pottinger, R.P. and E.J. LeRoux. 1971. The biology and dynamics of *Lithocolletis blancardella* (Lepidoptera: Gracillariidae) on apple in Quebec. Memoirs of the Entomological Society of Canada 77. 437 pp.

Powers, N.R. and E.R. Oatman. 1984. Biology and temperature responses of *Chelonus kellieae* and *Chelonus phthorimaeae* (Hymenoptera: Braconidae) and their host, the potato tuberworm, *Phthorimaea operculella* (Lepidoptera: Gelechiidae). Hilgardia, 52(9):1-31.

Rahman, M. 1970. Effect of parasitism on food consumption of *Pieris rapae* larvae. Journal of Economic Entomology, 63:820-821.

Ridgway, N.M. and D.L. Mahr. 1985. Natural enemies of the spotted tentiform leafminer, *Phyllonorycter blancardella* (Lepidoptera: Gracillariidae), in sprayed and unsprayed apple orchards in Wisconsin. Environmental Entomology, 14:459-463.

Sekita, N. and M. Yamada. 1979. Studies on the population of the apple leafminer *Phyllonorycter ringoniella* Matsumura. III. Some analyses of the mortality factors operating upon the population. Applied Entomology and Zoology, 14:137-148.

Stoner, A. and R.E. Weeks. 1976. *Copidosoma truncatellum*, a polyembryonic parasite of *Trichoplusia ni*: age of host eggs parasitized, searching, fecundity, and effectiveness. Environmental Entomology, 5:323-328.

Tachikawa, T. 1966. On an important parasite of the apple leaf miner. Nogyo ayobi Engei, 41:95-97.

Wang, T. and J.E. Laing. Polyembryony in *Holcothorax testaceipes* (Ratzeburg) (Hymenoptera: Encyrtidae). Annals of the Entomological Society of America. (In Press)

Weires, R.W., D.R. Davis, J.R. Leeper, and W.H. Reissig. 1980. Distribution and parasitism of gracillariid leafminers on apple in the northeast. Annals of the Entomological Society of America, 73:541-546.

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EFFECT OF FLOODING ON SURVIVAL OF THE ONION FLY *DELIA ANTIQUA* (DIPTERA: ANTHOMYIIDAE) AND TWO PARASITOIDS, *APHAERETA PALLIPES* (HYMENOPTERA: BRACONIDAE) AND *ALEOCHARA BILINEATA* (COLEOPTERA: STAPHYLINIDAE)

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Abstract *Proc. ent. Soc. Ont.* 120:43-47 (1989)

Effects of submersion duration on puparia of the onion pest *Delia antiqua* (Meigen) and larvae of two parasitoids, *Aphaereta pallipes* (Say) and *Aleochara bilineata* (Gyllenhal), were determined in controlled experiments carried out in the laboratory. Survival of *A. pallipes* was as good as or greater than that of *D. antiqua* at 1° and 20°C respectively, while *A. bilineata* survival was less than that of the host at both temperatures. Potential problems could arise between the use of flooding as a disease or pest control tool and its effect on non-target beneficial species.

Introduction

Unusual weather, such as hurricanes or torrential downpours, can indirectly control insect populations. In 1954, Hurricane Hazel flooded the Holland Marsh resulting in greatly reduced populations of the carrot pest, *Psila rosae* (Fabr.) being observed the following spring (Backs 1957). Direct manipulation of the soil environment, by either flooding of fields (Moore 1949) or combinations of flooding and drying cycles (Johnson and Berger 1972) has also been attempted for control of various plant pathogens and nematodes that attack vegetable crops. Periods of flooding range from a few weeks to several months in tropical and sub-tropical regions (Moore 1949; Stover *et al.* 1953). Leggett and Rahe (1985) found that, in British Columbia, long term soil saturation through winter flooding of fields infected with onion white rot, *Sclerotium cepivorum* Berk. caused increased rates of decay of sclerotia. Recently, researchers have proposed flooding of onion fields in Ontario as a means of controlling onion white rot, sclerotinia white mold and root knot nematode (Edgington 1988).

Flooding, like other forms of generalized pest control, affects "non-target" areas of the agricultural ecosystem including insect pests and insect parasitoids and predators. For example, survival of the onion fly, *Delia antiqua* (Meigen) and two common parasitoids in Ontario, *Aphaereta pallipes* (Say), and *Aleochara bilineata* (Gyllenhal) (Tomlin *et al.* 1985) may be affected by flooding. The relative susceptibility of the pest and its parasitoids could have significant effects on these population levels with economic implications for management of the pest population.

We report here on laboratory experiments designed to determine the flooding periods required to significantly reduce survival, at temperatures either well above or below the developmental thresholds, of puparia of *D. antiqua* and larvae of both *A. pallipes* and *A. bilineata*. These life stages normally occur in the soil and would be most affected by flooding.

Materials and Methods

Insects for all experiments came from laboratory-reared cultures maintained at the London Research Centre. Rearing techniques have been described elsewhere (Harris *et al.* 1984; Whistlecraft *et al.* 1984, 1985). Tests were conducted from May 1986 to March 1988.

Two experimental regimes were selected: flooding of puparia and parasitoid larvae at 1°C, 0:24 L:D to simulate cold weather during which the insects could be expected to be in a state of diapause, and flooding of the same life stages at 20°C, 16:8 L:D to simulate a period of active development typical of warm weather.

(a) *D. antiqua*: Puparia from 1°C storage that had completed at least 8 weeks chilling to fulfil cold requirements (Tolman *et al.* 1985) were used for each test. Groups of 10 puparia were mixed with 20 ml of moistened, sterilized muck:Plainfield sand (2:1 v/v), a commonly used soil mixture at our laboratory. Each group was then transferred to a 6 cm x 8 cm x 1 cm screened bag subsequently stapled closed to prevent loss of puparia. Once sealed, the bags were individually buried 2.5 cm deep in moist soil mixture in a 450 ml plastic tub. Each tub was gently flooded with de-ionized water until the soil was submerged to a depth of 1 cm. Control puparia were set in bags as above but were not flooded. At 20°C flooding temperature, each trial was replicated three times, with flooding periods ranging from zero to four weeks. At 1°C, four replications were set with flooding periods ranging from zero to ten weeks. To prevent evaporative water loss, all tubs were covered with a solid plastic lid.

After flooding for the desired time period, all puparia were recovered and placed in clear gelatin capsules (size 000) for incubation at 20°C, 16:8 L:D, 65 ± 5% RH. Numbers of successfully eclosed flies were recorded.

(b) *A. pallipes*: *A. pallipes* are gregarious parasitoids that overwinter as mature larvae inside puparia of various dipteran hosts including *D. antiqua* (Whistlecraft, unpublished). Infested puparia from 1°C cold storage were examined using a binocular microscope to ensure that all were parasitized. Groups of 10 parasitized puparia were flooded, as described in (a) above, for periods ranging from zero to twelve weeks at both 1°C and 20°C with each trial replicated four times. After flooding, all puparia were recovered from the screened bags and placed in moist soil mixture in 450 ml plastic tubs at 20°C for further incubation and eclosion. Once all parasitoid eclosion had ceased, host puparia were examined for exit holes and parasitoid survival rates calculated.

(c) *A. bilineata*: *A. bilineata* are solitary pupal parasitoids of various Diptera, including *D. antiqua*, that overwinter as first instar larvae within host puparia (Whistlecraft *et al.* 1985). Diapausing *D. antiqua* that had been chilled at 1°C for at least 8 weeks to satisfy cold requirements were examined to ensure that all host puparia were parasitized. Groups of 10 parasitized host puparia were flooded as described in (a) above for up to 5 weeks at 20°C and 6 weeks at 1°C with each trial replicated four times. After flooding all puparia were removed from the bags and placed in a moist soil mixture for incubation and subsequent observation of eclosion rates as described in (b) above.

After completion of each experiment, results were analyzed using an arc sine transformation of percentage eclosion rates of all replicates within each trial and then tested for significance of flooding duration using ANOVA.

Results

The use of screened bags ensured that all insects remained submerged throughout the entire flooding period. At 20°C flooding, significantly reduced survival (P=0.01) occurred in all three species. Survival times varied, however, ranging from less than one week for *A. bilineata* to at least 8 weeks for *A. pallipes* (Table I). Variability in parasitoid survival can,

TABLE I. Survival of three insect species subjected to flooding either during diapause or active development.

Species/Lifestage	Duration of Flooding (weeks)	Mean % eclosion at indicated temp.	
		20°C	1°C
Delia antiqua	0	90.0 a*	97.5 a
puparia	1	93.3 a	-
	2	43.3 b	77.5 b
	3	3.3 b	-
	4	0.0 b	92.5 ab
	6	-	90.0 ab
	8	-	82.5 ab
	10	-	87.5 ab
Aphaereta pallipes	0	92.5 ab	85.0 a
mature larvae	2	100.0 a	92.5 a
	4	90.0 ab	80.0 a
	6	75.0 b	100.0 a
	8	87.5 ab	100.0 a
	10	17.5 c	92.5 a
	12	12.5 c	92.5 a
Aleochara bilineata	0	82.5 a	75.0 a
first instar larvae	1	12.5 b	82.5 a
	2	2.5 b	83.3 a
	3	17.5 b	75.0 a
	4	0.0 b	70.0 a
	5	0.0 b	22.5 b
	6	-	32.5 b

*with each experiment numbers followed by same letter are not significant at P=0.01 (Duncan's Multiple Range Test)

at least partially, be explained by the type of parasitism. *A. bilineata*, a pupal ectoparasitoid, enters the host as a first instar larva that chews a small hole in the host puparium (Bromand 1980). A plug of cementum, composition unknown, is then secreted to block the opening. This plug can easily be displaced by shaking or soaking, allowing access to the interior for pathogens and water. *A. pallipes* is an endoparasitoid that hatches, after host pupation, from eggs laid in the host during the larval stage (Salkeld 1959). Consequently, the host puparium remains intact preventing leakage of water or entrance of pathogens during submersion. In addition to these physical differences of parasitism, other physiological differences may exist that enable *A. pallipes* to withstand longer periods of anaerobic conditions than its host. The increased survival potential of *A. pallipes* would be potentially advantageous for pest managers utilizing flooding for control of onion pathogens during warmer temperatures.

At 1°C, which was below the minimum developmental threshold for all three species (Whistlecraft *et al.* 1984, 1985), *A. bilineata* again suffered the most rapid decline in survival (P=0.01), followed by *D. antiqua* with much slower decline and *A. pallipes* with no decrease even after 12 weeks submersion. Consequently, flooding during cold weather could potentially eliminate most *A. bilineata* with no substantive effect on reducing the pest species. Of interest was the observation that no pupal development took place in *D. antiqua* during warm temperature flooding, even through 20°C approaches optimum growth temperatures for all three species. Mean eclosion times of 16.9±1.48, 17.61±1.19, 17.93±1.23 days were recorded for *D. antiqua* adults that had been submerged for 0, 1, and 2 weeks respectively. Similar results were recorded for *A. pallipes* at 20°C. These findings require alteration of calculations of degree-day development for insect populations in fields flooded for disease control at temperatures that are above the development thresholds for insect species concerned (Whitfield *et al.* 1985).

This work describes just one more example for the need to develop a complete picture of potential impact of various broad spectrum pest control techniques that are in place or planned for future use in agricultural systems.

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References

Backs, R.H. 1957. Note on effect of flooding on the carrot rust fly in the Holland marsh area of Ontario. Canadian Entomologist, 89:89-90.

Bromand, B. 1980. Investigations on the biological control of the cabbage rootfly (*Hylemya brassicae*) with *Aleochara bilineata*. International Organization for Biological Control of Noxious Pests and Animals - West Palearctic Regional Section, Bulletin III 1:49-62.

Harris, C.R., J.W. Whistlecraft, H.J. Svec, J.H. Tolman, and A.D. Tomlin. 1984. Outdoor rearing technique for mass production of onion maggots (Diptera: Anthomyiidae). Journal of Economic Entomology, 77:824-827.

Johnson, S.R. and R.D. Berger. 1972. Nematode and soil fungi control in celery seedbeds on muck soil. Plant Disease Reporter, 56:661-664.

Leggett, M.E. and J.E. Rahe. 1985. Factors affecting the survival of sclerotia of *Sclerotium cepivorum* in the Fraser Valley of British Columbia. Annals of Applied Biology, 106:255-263.

Moore, W.D. 1949. Flooding as a means of destroying the sclerotia of *Sclerotinia sclerotiorum*. Phytopathology, 39:920-927.

Salkeld, E.H. 1959. Notes on anatomy, life-history, and behaviour of *Aphaereta pallipes* (Say (Hymenoptera: Braconidae), a parasite of the onion maggot, *Hylemya antiqua* (Meig.). Canadian Entomologist, 91:93-97.

Stover, R.H., N.C. Thornton, and V.C. Dunlap. 1953. Flood-fallowing for eradication of *Fusarium oxysporum* F. *cubense*: I. Effect of flooding on fungus flora of clay loam soils in Ulua Valley, Honduras. Soil Science, 76:225-238.

Tolman, J.H., J.W. Whistlecraft, and C.R. Harris. 1985. Rearing of *Delia* spp. *Delia antiqua*. *In*: P. Singh and R.F. Moore (eds.) Handbook of Insect Rearing, Vol. 2. Elsevier Publishers, B.V. Amsterdam, pp. 49-57.

Tomlin, A.D., J.J. Miller, C.R. Harris, and J.H. Tolman. 1985. Arthropod parasitoids and predators of the onion maggot (Diptera: Anthomyiidae) in southwestern Ontario. Journal of Economic Entomology, 78:975-981.

Whistlecraft, J.W., C.R. Harris, A.D. Tomlin, and J.H. Tolman. 1984. Mass rearing technique for a braconid parasite, *Aphaereta pallipes* (Say) (Hymenoptera: Braconidae). Journal of Economic Entomology, 77:814-816.

Whistlecraft, J.W., C.R. Harris, J.H. Tolman, and A.D. Tomlin. 1985. Mass-rearing technique for *Aleochara bilineata* (Coleoptera: Staphylinidae). Journal of Economic Entomology, 78:995-997.

Whitfield, G.H., R.I. Carruthers, and D.L. Haynes. 1985. Phenology and control of the onion maggot (Diptera: Anthomyiidae) in Michigan onion production. Agriculture, Ecosystems and environment, 12:189-200.

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LEAF-DISK REARING TECHNIQUE FOR THE PRODUCTION OF ALATE GREEN PEACH APHIDS, *MYZUS PERSICAE* (HOMOPTERA: APHIDIDAE)

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Abstract

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Rearing green peach aphids, *Myzus persicae* (Sulzer), on leaf disks of potato in 9 x 50 mm petri dishes produced alates of uniform size, a requirement for studying factors affecting wing production or evaluating differences between biotypes. At a density of about eight aphids per petri dish, alate *M. persicae* were similar in size and uniformity to individuals trapped in the field. After several generations on leaf disks, 40 to 52% of the offspring produced were alates.

Keywords: Insecta, colony, potato, reproduction.

Introduction

Methods for rearing apterous aphids on whole plants, synthetic diets, leaf disks, or parts of plants have been reported frequently (Adams and van Emden 1972). Disks excised from leaves and floated on nutrient solutions or distilled water have been used to rear aphids in studies of aphid polymorphism (Johnson 1966; Schaefers and Judge 1971). Although this rearing technique is suitable for many studies of aphid wing production, it is rarely used for the mass rearing of alatae. The large numbers of alate aphids required for studies of flight and virus transmission usually come from colonies of aphids caged on whole plants (MacGillivray and Anderson 1957). Although the various rearing methods are frequently compared with each other, the size of alatae produced under these various rearing conditions has seldom been compared with those collected from the field.

The objective of this study was to develop a simple method of producing a reliable supply of alate green peach aphids, *Myzus persicae* (Sulzer) on leaf disks of potato. The suitability of the technique was determined by comparing the size of alatae reared on leaf disks with alatae from the field and from caged whole plants, a commonly used rearing technique for alates.

Materials and Methods

The rearing method used in this study was adapted from a method for rearing individual apterous green peach aphids on leaf disks of potato (Lowery and Sears 1986). Leaf disks were cut with a cork borer (22 mm diameter) from the lowest leaves of cv. 'Katahdin' potato, beginning one to two weeks before flowering. Preliminary tests demonstrated that more alate offspring were produced when slightly yellow, senescing leaves were used as the food source. Potato plants were grown in the greenhouse in clay pots (15 cm diameter) containing a commercial potting media (Pro Mix®). Plants were fertilized weekly (10:10:10) and grown under a photoperiod of 16:8 (L:D).

Two apterous, reproducing green peach aphids were placed on three overlapping leaf disks of potato in each petri dish (50 by 9 mm) with 10 small holes burned into the tight-fitting lids for ventilation. Dishes were placed upside down on moist Kimwipes® inside large clear plastic containers. This position allows for limited air and moisture exchange, while preventing aphids from escaping. After 24 h, the adults were removed and eight or 15 first instar nymphs were distributed per dish. Dishes were held at room temperature under indirect constant fluorescent light. Leaf disks were replaced three times per week and small amounts of distilled water were added to the paper towelling to keep it slightly moist. Mature alate green peach aphids were removed for examination while two apterous individuals per dish were placed on new leaf disks to begin the next rearing cycle.

The size of alate green peach aphids reared on leaf disks of potato was compared with individuals reared on whole, caged potato plants in the greenhouse (MacGillivray and Anderson 1957), and with specimens collected in 1985 from yellow pan traps in fields of potato at the Research Station in Fredericton, and throughout the province. Alatae from the greenhouse were collected from sparsely colonized whole plants with 15-20 alatae present in the colonies or on the cage screening, and from densely colonized potatoes producing at least 70-100 alatae per day.

Four body measurements, including body length from vertex to base of cauda, length of hind tibia, length of cornicle, and antennal length from segment II to VI, were made at 40X from unmounted aphids in 70% alcohol using a micrometer eyepiece. Data were subjected to analysis of various and differences between treatments were tested for significance ($P < 0.05$), using the Student-Newman-Keuls Test (Zar 1974).

Numbers of alate offspring produced on leaf disks of potato were determined for apterae derived from a greenhouse colony or from the field. The effect of parental rearing conditions on production of alate offspring was studied for aphids reared for more than two generations on leaf disks (continuous production), for parental aphids reared on leaf disks for one generation, and for parental aphids transferred directly from greenhouse plants to leaf disks. Aphids were reared at a density of 8 per dish in both studies.

Results and Discussion

Alate green peach aphids reared at a density of eight per dish on leaf disks of potato were similar ($P > 0.05$) in body and cornicle size to alate green peach aphids collected in yellow pan traps but had longer ($P < 0.05$) antennae and tibia (Table I). Aphids reared at a density of 15 per dish had significantly ($P < 0.05$) shorter antennae, cornicles and body than aphids from the field, but were similar ($P > 0.05$) to those from a densely infested colony reared on whole plants in the greenhouse. In this study, caged potato plants heavily infested with aphids had not deteriorated to a great extent and were still actively growing. Aphids smaller than those measured in this study could be expected as time progressed. Alate green peach aphids produced on greenhouse potatoes will vary in size with changes in the density of the aphid colony and the condition of the host plant. When colony density increased, large numbers of alatae were produced and aphid size decreased. In the field, alate forms are produced in response to crowding, deterioration of host quality, changes in day length, or a combination of these factors (Dixon 1985). Lengths of antennae and legs are correlated with aphid size, which is affected by the nutritional quality of the host plant (Dixon 1985). Rearing aphids on leaf disks of potato may produce alatae of a more uniform size since leaf disks provide a uniform substrate which reduces the variability of rearing conditions (Adams and van Emden 1972). In our studies, no significant differences in size occurred among several rearing cycles.

The dimensions of the hind tibia and cornicles of naturally occurring alate viviparous *M. persicae* from yellow pan traps were within the ranges of measurement recorded by

TABLE I. Morphological measurements (mm) for alate green peach aphids, *M. persicae*, reared at different densities on leaf disks of potato and whole potato plants, or collected from the field in pan traps.

Aphid Source	Sample size (n)	X ± SEM			
		Antenna	Hind tibia	Cornicle	Body
Leaf disks, (8/dish)	47	2.02(0.016)a[1]	1.31(0.010)a	0.39(0.005)a	1.82(0.019)b
Leaf disks, (15/dish)	13	1.70(0.038)c	1.11(0.035)b	0.35(0.009)b	1.54(0.034)d
Greenhouse plants, uncrowded	15	1.93(0.053)b	1.33(0.032)a	0.35(0.008)b	1.68(0.065)c
Greenhouse plants, crowded	22	1.80(0.034)c	1.12(0.024)b	0.34(0.007)bc	1.51(0.026)d
Pan traps, Fredericton	27	1.90(0.031)b	1.17(0.021)b	0.38(0.006)a	1.87(0.038)b
Pan traps, New Brunswick[2]	18	1.93(0.040)b	1.18(0.023)b	0.38(0.010)a	1.99(0.038)a

[1] Means followed by different letters within columns are significantly different (P<0.05; Student-Newman-Keuls Test preceded by analysis of variance [F = 14.79, df = 5,136, P<0.01 for antenna; F=20.83, df = 5.136, P<0.01 for tibia; F = 8.14, df = 5,136, P<0.01 for cornicle; F = 25.80, df = 5,136, P<0.01 for body]).

[2] Alates collected in yellow pan traps from various locations in New Brunswick as part of the 1985 Aphid Alert Program.

Mason (1940), Palmer (1952), and Blackman (1987). The antennal lengths we recorded were shorter than those determined by Palmer (1952), but similar to those reported by Mason (1940). Average body lengths of aphids from the greenhouse and from crowded leaf disks were smaller than those recorded by either Mason (1940) or Palmer (1952). That may have resulted from the rearing conditions or from the reaction of unsclerotized tissue to trap solutions and preserving fluids. Body lengths of alatae reared at a density of 8 per dish or from field traps were similar to those recorded by Palmer (1952).

Mature, reproducing apterous green peach aphids transferred from uncrowded greenhouse colonies to leaf disks and allowed to deposit young produced only 8% alatae. After one generation on leaf disks, 24% of offspring were winged, and after two or more generations on leaf disks, alate production averaged 40% (Table II). The latter rate is similar to the rate (52%) of alate production obtained with field-collected *M. persicae* after more than two generations on leaf disks (Table II). Kennedy and Stroyan (1959) demonstrated that rearing conditions of the parental and grandparental aphids have an effect on the production of alate morphs. Other biological properties of aphids, such as fecundity, size, and developmental rate, are partly determined while the aphid is developing within the mother (Adams and van Emden 1972). These factors must be taken into consideration in the production of aphids for scientific studies.

The rearing system outlined in this study produces a reliable supply of winged green

TABLE II. Effect of source of aphids and previous rearing of parental aphids on production of alate morphs of *M. persicae* on leaf disks of potato.

Aphid Source	Previous rearing	Total no. of aphids reared	Percentage alates
Field potato	Potato leaf disks (continuous)	694	52
Greenhouse colony	Potato leaf disks (continuous)	648	40
Greenhouse colony	Potato leaf disks (one generation)	106	24
Greenhouse colony	Greenhouse (whole plant)	109	8

peach aphids of a uniform size comparable with the size and uniformity of those from the field. Aphids in each petri dish were the same age, and newly emerged alatae could be collected and used in various studies. Because leaf disks provided a uniform substrate (Adams and van Emden 1972), this rearing technique may be useful for examining factors that affect wing production or differences between aphid biotypes, and it provided an alternative technique to the flotation of leaf disks on solutions of water.

The technique requires some practice to achieve the optimal balance of moisture but it has the advantage of minimizing direct handling of the aphids. By replacing only the oldest disk every two or three days, aphids are allowed to move to suitable disks on their own. Although no rearing technique can entirely eliminate the differences between natural and laboratory-reared aphids, the utilization of this technique reduces some of the differences, making it a viable alternative to the production of alatae on whole plants.

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References

Adams, J.B. and H.F. van Embden. 1972. The biologic properties of aphids and their host plant relationship. *In*: H.F. van Emden (ed.), Aphid Technology. Academic Press, London, U.K., pp. 47-104.

Blackman, R.L. 1987. Morphological discrimination of a tobacco-feeding form from *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), and a key to new world *Myzus nectarosiphon* species. Bulletin of Entomological Research, 77:713-730.

Dixon, A.F. G. 1985. Structure of aphid populations. Annual Review of Entomology, 30:155-174.

Johnson, B. 1966. Wing polymorphism in aphids. IV. The effect of temperature and photoperiod. Entomologia Experimentalis and Applicata, 9:301-313.

Kennedy, J.S. and H.L.G. Stroyan. 1959. Biology of aphids. Annual Review of Entomology, 4:139-160.

Lowery, D.T. and M.K. Sears. 1986. Effect of exposure to the insecticide azinphosmethyl on reproduction of green peach aphid (Homoptera: Aphididae). Journal of Economic Entomology, 79:1534-1538.

MacGillivray, M.E. and G.B. Anderson. 1957. Three useful insect cages. Canadian Entomologist, 89:43-46.

Mason, P.W. 1940. A revision of the North American aphids of the genus *Myzus*. USDA, Miscellaneous Publication, No. 371.

Palmer, M.A. 1952. Aphids of the Rocky Mountain Region. Thomas Say Foundation, Denver, 452 pp.

Schaefers, G.A. and F.D. Judge. 1971. Effects of temperature, photoperiod, and host plant on alary polymorphism in the aphid, *Chaetosiphon fragaefolii*. Journal of Insect Physiology, 17:365.379.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Englewood Cliffs, N.J., 620 pp.

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APPLE MAGGOT, *RHAGOLETIS POMONELLA* (DIPTERA: TEPHRITIDAE), RESPONSE TO TRAPS, SYNTHETIC LURES AND ADHESIVE IN FIELD TESTS IN ONTARIO

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Abstract *Proc. ent. Soc. Ont.* 120:55-64 (1989)

The standard trap for apple maggot (AM), *Rhagoletis pomonella* (Walsh), presently used in Ontario was more effective in trapping AM flies as compared to the Ladd® trap. The number of AM flies trapped was 1.6 to 8.7 times higher on the standard traps than on the Ladd® traps over the two years tested at two locations. The use of polystyrene disposable red spheres did not reduce the effectiveness of the traps. Aerosol tangle-trap used as the trap adhesive reduced AM fly catches by 38 and 46% as compared to the brush-on and spreadable formulations of adhesive. Odour enhanced lures improved efficiency of traps under some conditions.

Introduction

Apple maggot (AM), *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae), is a serious pest attacking apple fruit in eastern North America. Kring (1970) reported that red spheres and yellow panels used together were more efficient than either used alone to trap AM flies. The yellow panel is considered to be a foliage mimic eliciting a feeding-site response (Prokopy 1968). The red spheres act as a fruit mimic eliciting mating and oviposition type responses (Prokopy 1968). In Ontario, a combination of red spheres and Pherocon® prebaited yellow AM panels are used to monitor AM flies in commercial orchards. However, the effectiveness of AM traps (Reissig 1977) is less than that achieved with sex pheromone traps for lepidopterous pests in orchards.

Attempts have been made to improve the efficiency of AM traps by changing the size of the red spheres (Prokopy 1977), by the positioning of the trap within the tree canopy (Reissig 1975b; Swift 1982; Drummond *et al.* 1984), by using different traps (Reissig 1975a; Neilson *et al.* 1981; Swift 1982; Drummond *et al.* 1984; Aliniazee *et al.* 1987) and by incorporating synthetic apple volatiles (Reissig *et al.* 1982; Swift 1982; Reissig *et al.* 1985; Aliniazee *et al.* 1987). Aliniazee *et al.* (1987) reported that Ladd® yellow rectangles with red hemispheres in the centre and a Ladd® apple volatile attractant performed better than Pherocon® prebaited AM and red sphere traps with or without volatile attractants in attracting AM flies in an unsprayed orchard in Oregon. Reissig *et al.* (1985) reported that red spheres baited with synthetic volatile chemicals were two to four times more effective than unbaited red spheres and more than 50 times more effective than Pherocon® prebaited AM yellow panels when used in commercial orchards in New York State to trap AM flies. However, baited spheres were no more effective than unbaited spheres in abandoned orchards. They gave no explanation for this difference.

The present study was conducted to compare the effectiveness of several trap types which incorporate both red spheres and yellow panels to the standard AM trap presently used in Ontario. The effectiveness of odour enhanced lures, and the type of adhesive used on the traps as it affected AM fly catches was also investigated.

Materials and Methods

Smithfield Experimental Farm orchard.

The orchard used in this study consisted of 0.4 ha of McIntosh and Quinte apple cultivars, *Malus domestica* (Borkh), growing on Ottawa clonal (Heeney 1981) and Ottawa hybrid (Spangelo 1971) rootstocks. The orchard was planted in 1967 with a spacing of 6.1 m between rows and 3.7 to 6.1 m between trees within the row, however, some trees have since been removed. The orchard has received only one insecticide spray annually at calyx since 1983 and was known to have a high population of apple maggot. Fungicide sprays have been applied to control apple scab, *Venturia inaequalis* (Cke.) Wint.

Ten uniformly sized McIntosh trees with fruit were selected from within the orchard as trap trees. Each tree was divided into quadrants (north, south, east and west) and a trap was randomly assigned to each quadrant, with each tree serving as a replicate. Traps were hung approximately 1.5 m above ground level so that the traps were clearly visible from outside of the tree canopy. Traps were checked twice a week and traps were rotated one position in a clockwise direction after each inspection to minimize the effect of tree position on trap performance.

The four traps used were: (1) a standard trap consisting of a Pherocon® AM (Trece Incorporated, Salinas, California, U.S.A. 93915) prebaited yellow panel (14.0 x 23.0 cm) and two 7.0 cm diameter red polyethylene spheres placed approximately 0.5 m on each side of the yellow panel; (2) a standard trap with a Ladd® (Ladd Research Industries, Burlington, Vermont, U.S.A. 05402) odour enhanced lure attached to the top of either the right or left red sphere (randomly allocated); (3) a Ladd® AM fly trap which consisted of a 21.0 x 28.0 cm yellow polyethylene panel with a 9.0 cm diameter red polyethylene hemisphere on the centre of each side of the yellow panel; and (4) a Ladd® trap with an odour enhanced lure attached to the yellow panel just above the red sphere. The yellow panel on the Ladd® traps and the red spheres on all traps were coated with an aerosol formulation of tangle-trap (The Tanglefoot Company, Grand Rapids, Michigan, U.S.A. 49504).

In 1987, traps were placed in the orchard on 22 June and checked twice a week, usually Mondays and Thursdays. On each trap check day, the number of AM flies was recorded separately for each red sphere and yellow panel. AM flies and other debris were removed from the trap surface and a light coating of tangle-trap was reapplied if necessary to maintain a sticky surface. Yellow panels used with the standard traps were replaced every two weeks and the odour enhanced lures were replaced every three weeks. The traps were removed from the orchard on 27 August, 1987. In 1988, traps were placed in the orchard on 4 July, checked twice a week as in 1987, and removed from the orchard on 1 September.

The mean numbers of AM flies per trap were subjected to analysis of variance using a randomized complete block design with each tree (replicate) serving as a block (Steel and Torrie 1980). The treatment sum of squares for trap type and lure were partitioned separately. Where a significant ($P<0.05$) trap type x lure interaction occurred, the treatment sum of squares for traps was partitioned for individual orthogonal comparisons.

London orchard.

This site was a 0.6 ha abandoned orchard consisting of 26 apple trees spaced 10.7 x 10.7 m, however, some trees had been removed. The trees were of unknown cultivars, *M. domestica*, approximately 60 years old, on seedling rootstocks. No pesticides had been applied to this orchard for at least five years and it was known to have a high AM population. Five trap trees were randomly selected from within the orchard, avoiding exterior trees. Each tree was used as a replicate with the four traps placed equidistantly around the perimeter of the tree. Traps were hung at approximately 1.5 m above ground level and foliage was removed from within 30 cm of the trap so that it was clearly visible from outside of the tree canopy.

The four traps used were: (1) a standard unbaited trap as described for the Smithfield Experimental Farm site; (2) a standard trap with the red spheres coated with a spreadable formulation of tangle-trap (The Tanglefoot Company) that was applied with a knife; (3) a Ladd® AM fly trap (unbaited) as described for the Smithfield site; and (4) a disposable trap consisting of a Pherocon® AM prebaited yellow panel and two disposable 7.0 cm diameter red polystyrene spheres (Olsen Products, Medina, Ohio, U.S.A. 44258) coated with a brush-on formulation of tangle-trap. In 1988, the same traps were used except that traps 2, 3 and 4 were coated with the brush-on formulation of tangle-trap as used on the disposable trap in 1987. In both years, the aerosol formulation of adhesive was reapplied as necessary during the season to maintain a sticky surface. The other formulations of adhesive did not need to be reapplied.

In 1987, traps were placed in the orchard on 15 June and checked three times a week, usually on Mondays, Wednesdays and Fridays. Traps were removed from the orchard on 25 August, 1987. In 1988, traps were placed in the orchard on 16 June, checked twice a weeks, usually on Tuesdays and Fridays, and removed from the orchard on 19 August, 1988. Traps were maintained as indicated at the Smithfield location except the Pherocon® yellow panels were replaced only once in late July each year.

All AM flies removed from the traps were placed in labelled jars containing turpentine to remove the adhesive. Two to three days later, they were transferred to vials containing 85% ethyl alcohol. The sex of each AM fly was determined by counting the number of white bands on the abdomen (four on the female and three on the male). In some instances, the number of male and female flies was less than the total because the sex of some flies could not be determined. In 1988, the female AM flies were dissected under a binocular microscope and the presence of eggs was used as an indication of sexual maturity.

The mean number of AM flies trapped per date, starting at first AM fly catch, was subjected to analysis of variance using a randomized complete block design with date as a second blocking factor (Steel and Torrie 1980). When a significant "F" value was obtained ($P<0.05$), means were separated using Duncan's multiple range test ($P=0.05$). An additional analysis of variance was conducted to compare male and female catches for each trap.

Results

Smithfield Experimental Farm orchard.

In 1987, the trap type x lure interaction was not significant ($P>0.05$) (Table I). The standard trap caught more AM flies on the red spheres and on the yellow panel as compared to the Ladd® trap. The odour enhanced lure marginally increased ($P=0.07$) the performance of the traps. Although differences occurred in the numbers caught between traps, seasonal trends in the AM population were similar for all traps (Fig. 1). The number of AM flies caught on the standard traps was greater than on the Ladd® traps from 29 June until 13 August. From 17 to 27 August, the number of AM flies trapped was low for all trap types.

Over three times as many AM flies were trapped in 1988 (4,407) as in 1987 (1,374). The Ladd® traps showed the greatest increase in numbers caught from 1987 to 1988. In 1988, the trap type x lure interaction was not significant ($P=0.22$) for the AM fly catches on the yellow panel (Table II). The standard trap caught more AM flies as compared to the Ladd® trap. The odour enhanced lure also increased trap catches on the yellow panel, particularly with the Ladd® trap where the mean number of AM flies trapped was increased from 24.0 to 61.9. The trap type x lure interaction was significant (P<0.01) for the AM fly catches on the red spheres and total trap catch. The partitioning of sums of squares indicated that without the use of the lure, the standard trap caught more AM flies than did the Ladd® trap (F=15.3; df=1,9; P<0.01 and F=14.9; df=1,9; P<0.01 for red sphere and total, respectively). With the Ladd® trap, the lure increased catches as compared to the unbaited Ladd® trap (F=19.2; df=1,9; P<0.01 and F=19.2; df=1,9; P<0.01 for the red sphere and total, respectively). With the standard trap, there was no difference in AM fly catches on the baited red sphere as compared to the unbaited sphere.

TABLE I. Mean number ± SE[x] of apple maggot flies caught per trap from 22 June to 27 August, 1987 in Smithfield Experimental Farm orchard.

Trap type	Lure	Red spheres	Yellow panel	Total
Standard[y]	Ladd®	17.7±3.3	40.9±11.1	58.6±12.9
Standard[y]	No lure	16.8±3.3	35.2±11.9	52.0±12.9
Ladd®[z]	Ladd®	9.2±1.6	8.1± 1.4	17.3± 2.8
Ladd®[z]	No lure	4.2±1.2	5.3± 0.9	9.5± 1.7
P value trap type (T) (df=1,27)		0.01	0.01	0.01
P value lure (L) (df=1,27)		0.07	0.54	0.34
P value T x L (df=1,27)		0.20	0.83	0.94

[x] SE = standard error.

[y] Yellow panel plus two red spheres.

[z] Yellow panel with red hemisphere on each side.

Biweekly trap catches comparing the four traps are shown in Figure 2. The baited Ladd® trap caught more AM flies than did the unbaited Ladd® trap on all dates (7 July to 1 September, 1988). The standard traps caught more AM flies than did the Ladd® traps early in the season from 7 July to 21 July. During August, the baited Ladd® trap caught more AM flies than did the baited standard trap. However, when the unbaited traps were compared, the standard trap generally caught more AM flies than did the Ladd® trap.

London orchard.

A total of 2,631 AM flies were trapped during the 1987 season. First catch occurred on 26 June on a yellow panel (sex undetermined). The first female AM fly was trapped on 29 June on a red sphere. More AM flies were trapped on red spheres than on yellow panels through the rest of the season except on one date, 17 July. The disposable trap and standard trap with spreadable tangle-trap caught the greatest number of AM flies followed by the standard trap with aerosol tangle-trap and Ladd® trap (Table III). More AM flies were caught on the red spheres of the standard trap with spreadable tangle-trap than on the red spheres of standard trap with aerosol tangle-trap. No difference in the number of AM flies trapped on the yellow panels used with the standard traps or the disposable trap was detected.

During 1987, 1,300 male and 1,331 female AM flies were trapped (male:female ratio of 1:1). On the red spheres, the male:female ratio was 1:0.8. However, on the yellow panels, the ratio was 1:3.7. Significantly (P<0.01) more female than male AM flies were trapped on the yellow panels of the standard and disposable traps.

TABLE II. Mean number ± SE[x] of apple maggot flies caught per trap from 4 July to 1 September, 1988 in Smithfield Experimental Farm orchard.

Trap type	Lure	Red spheres	Yellow panel	Total
Standard[y]	Ladd®	51.5± 8.6	77.9±21.8	129.5±26.8
Standard[y]	No lure	71.7±17.3	67.0±16.3	138.7±30.3
Ladd®[z]	Ladd®	59.6±13.2	61.9±15.3	121.5±28.0
Ladd®[z]	No lure	27.0± 8.5	24.0± 7.0	51.0±15.3
P value trap type (T) (df=1,27)		0.02	0.01	0.01
P value lure (L) (df=1,27)		0.39	0.03	0.06
P value T x L (df=1,27)		0.01	0.22	0.01

[x] SE = standard error.

[y] Yellow panel plus two red spheres.

[z] Yellow panel with red hemisphere on each side.

Figure 3 shows the number of AM flies trapped for each date from 17 July to 25 August. Only 15 AM flies were caught before 17 July. The Ladd® trap generally had the smallest catch during the season.

A total of 1,354 AM flies were trapped in the London orchard in 1988. More AM flies were captured on the red spheres on all dates than on the yellow panels. The disposable trap and standard trap with brush-on tangle-trap caught more AM flies in total than did the standard trap with aerosol tangle-trap or the Ladd® trap (Table IV). The standard trap with brush-on tangle-trap caught more AM flies on the red spheres than did the same trap with aerosol tangle-trap. The Ladd® trap caught fewer AM flies on the red spheres than did the other traps with brush-on tangle-trap. There was no difference in AM fly catch on the yellow panels of the standard and disposable traps. More AM flies were trapped on the yellow panel of the Ladd® trap than on the other three traps.

The first AM fly trapped was a gravid female on a red sphere on 12 July, 1988. On 15 July, a gravid female was trapped on a yellow panel. Most AM flies trapped during 1988 were gravid, regardless of trap type or date (data not shown). During 1988, 611 male and 706 female AM flies were trapped (male:female ratio 1:1.2). On the red spheres, the male:female ratio was 1:1 and on the yellow panels, the ratio was 1:2.8. Significantly (P<0.05) more female than male AM flies were trapped on the yellow panels of the standard trap with aerosol tangle-trap and on the Ladd® and disposable traps.

Biweekly trap catches comparing the four traps are shown in Figure 4. Peak AM fly catch occurred from 29 July to 5 August. Although variation in trap performance occurred among dates, the disposable trap and standard trap with brush-on tangle-trap generally caught more AM flies than did the other two traps during the late July to mid-August period.

TABLE III. Mean number of apple maggot flies caught per trap[V] in London Orchard, 1987.

		Red spheres			Yellow panel			Red spheres + panel		
Trap type	Adhesive	Male	Female	Total	Male	Female	Total	Male	Female	Total
Standard[W]	Aerosol	2.3a[Z]	1.1b	3.4b	0.1b	0.7a	0.8ab	2.4b	1.8b	4.2b
Standard[W]	Spreadable	3.4a	3.4a	6.8a	0.1b	0.8a	1.0a	3.5ab	4.3a	7.8a
Ladd®[X]	Aerosol	0.3b	0.1c	0.4c	0.3a	0.2b	0.5b	0.6c	0.3c	0.9c
Disposable[Y]	Brush-on	4.1a	3.8a	7.9a	0.2ab	0.9a	1.1a	4.3a	4.7a	9.0a
Standard Error		0.6	0.3	0.8	0.05	0.1	0.1	0.6	0.3	0.8

[V] Traps checked three times per week. Data from 26 June to 25 August.

[W] Yellow panel plus two red spheres.

[X] Yellow panel with red hemisphere on each side.

[Y] Yellow panel plus two disposable red spheres.

[Z] Means followed by the same letter within each column are not significantly different using Duncan's multiple range test (P=0.05).

TABLE IV. Mean number of apple maggot flies caught per trap[V] in London Orchard, 1988.

		Red spheres			Yellow panel			Red spheres + panel		
Trap type	Adhesive	Male	Female	Total	Male	Female	Total	Male	Female	Total
Standard[W]	Aerosol	2.2ab	1.4b	3.7b	0.1	0.5b	0.6b	2.4ab	1.8b	4.3b
Standard[W]	Brush-on	2.8a	3.2a	6.2a	0.2	0.3b	0.7b	3.0a	3.6a	6.9a
Ladd®[X]	Brush-on	1.0b	1.1b	2.1b	0.4	1.1a	1.5a	1.4b	2.1b	3.6b
Disposable[Y]	Brush-on	3.3a	3.6a	6.9a	0.2	0.7b	0.9b	3.5a	4.3a	7.8a
Standard Error		0.5	0.3	0.7	0.1	0.1	0.2	0.5	0.4	0.7

[V] Traps checked twice a week. Data from 12 July to 19 August.

[W] Yellow panel plus two red spheres.

[X] Yellow panel with red hemisphere on each side.

[Y] Yellow panel plus two disposable red spheres.

[Z] Means followed by the same letter within each column are not significantly different using Duncan's multiple range test (P=0.05). Absence of letters indicates no significant difference.

Discussion

Our results over two seasons at Smithfield and London clearly showed that the standard AM trap presently used in Ontario was as effective or more effective in trapping AM flies than either the Ladd® or disposable traps. The improved performance of traps which used both red spheres and yellow panels as compared to either used alone was previously demonstrated by Kring (1970). The disposable trap used in our study (London 1987 and 1988) was as effective as the standard trap in trapping AM flies. The use of disposable red spheres offers the advantage of no cleaning and storing requirement from year to year. In

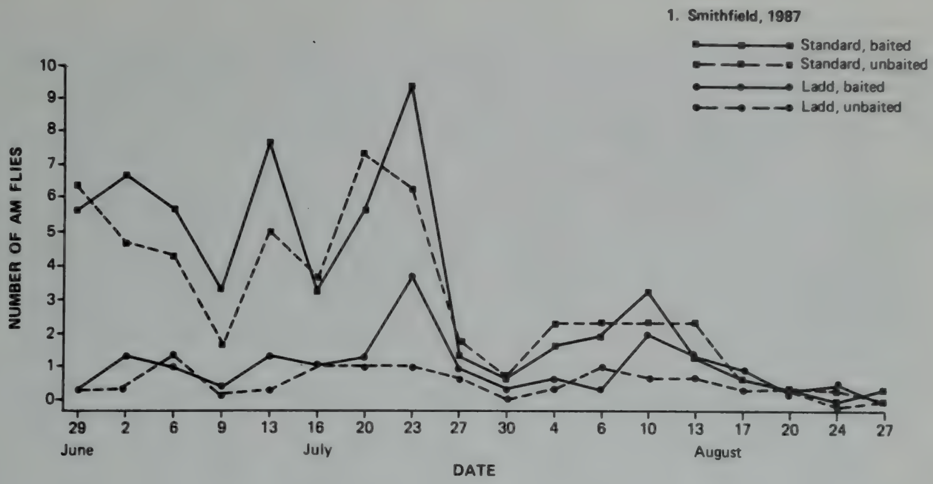

FIGURE 1. Biweekly trap catches of apple maggot, *Rhagoletis pomonella*, Smithfield Experimental Farm, 1987.

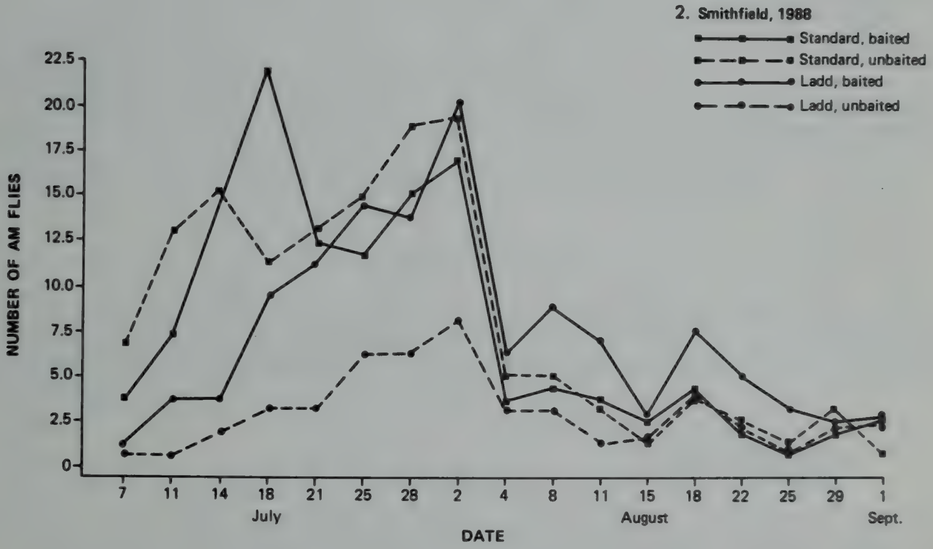

FIGURE 2. Biweekly trap catches of apple maggot, *Rhagoletis pomonella*, Smithfield Experimental Farm, 1988.

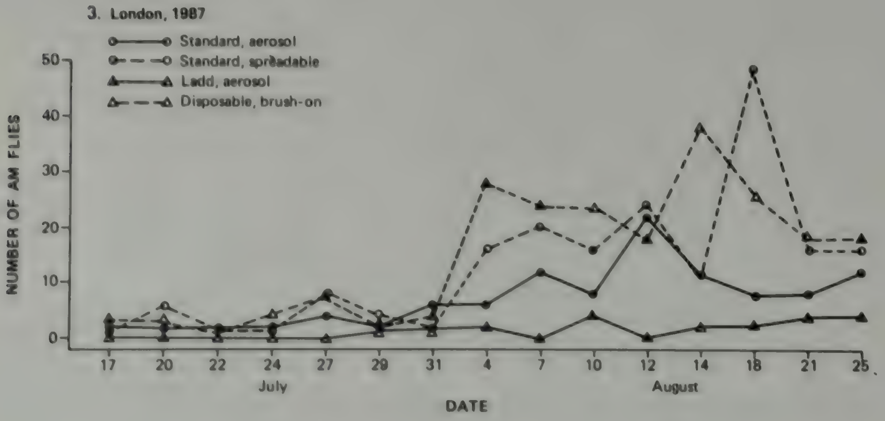

FIGURE 3. Triweekly trap catches of apple maggot, *Rhagoletis pomonella*, London, 1987.

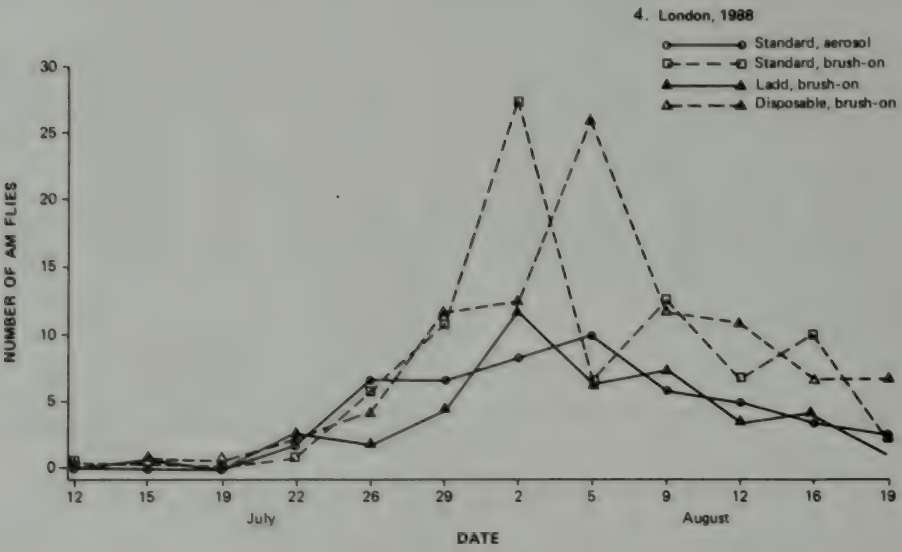

FIGURE 4. Biweekly trap catches of apple maggot, *Rhagoletis pomonella*, London, 1988.

our study, the Ladd® trap was inferior to the standard trap in catching AM flies. This may be partly explained by the smaller catching surface of the red hemispheres of the Ladd® trap as compared to the two red spheres used with the standard trap. Also, the Pherocon® yellow panel used with the standard trap was prebaited whereas on the Ladd® trap, only adhesive was used.

The findings from Smithfield from 1988 showed that the use of odour enhanced lures on the Ladd® traps increased AM fly catches as compared to the unbaited trap. That agrees with results reported by Aliniazee *et al.* (1987). Reissig *et al.* (1982, 1985) reported that baited red spheres caught more AM flies than did the unbaited spheres in commercial orchards. However, spheres baited with synthetic volatile lures were no more effective than unbaited spheres in abandoned orchards (Reissig *et al.* 1985). Our test orchard was managed as a commercial orchard except that fewer insecticide sprays were applied and the level of AM infestation was similar to that expected in an abandoned orchard. The large AM fly population in the Smithfield orchard may explain the lack of response to the lure used on the red spheres. Reissig *et al.* (1982) also noticed that volatile baited traps were relatively less effective in abandoned orchards where AM fly populations were large. The effectiveness of lures on red spheres was not dependent upon AM fly population in commercial orchards in New York State (Reissig *et al.* 1985), however, the number of AM flies they trapped was considerably lower than the number trapped in the Smithfield orchard. The effectiveness of the lure on the Ladd® trap did not appear to be affected by AM population since the baited Ladd® traps performed better in 1988 when the AM fly population was higher than in 1987. The relatively short period of effectiveness of the Ladd® lure (Jones 1988) may also explain why a greater response in AM fly catches was not obtained with the lure at Smithfield.

In this study, choice of adhesive affected AM trap performance. The aerosol tangle-trap was not only less effective in trapping AM flies but it also needed to be reapplied at intervals through the season to maintain a sticky surface. With the spreadable and brush-on formulations of adhesive, one application lasted throughout the season.

Our results show that the standard AM trap presently used in Ontario for monitoring AM activity is as effective as other traps tested, except that the aerosol tangle-trap should not be used. Odour enhanced lures may increase the effectiveness of the traps under some conditions, however, more research is needed to further define these conditions.

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References

Aliniazee, M.T., A.B. Mohammad, and S.R. Booth. 1987. Apple maggot (Diptera: Tephritidae) response to traps in an unsprayed orchard in Oregon. Journal of Economic Entomology, 80:1143-1148.

Drummond, F., E. Groden, and R.J. Prokopy. 1984. Comparative efficacy and optimal positioning of traps for monitoring apple maggot flies (Diptera: Tephritidae). Environmental Entomology, 13:232-235.

Heeney, H.B. 1981. Apple rootstock studies at the Smithfield Experimental Farm. Technical Bulletin No. 3. 51 pp.

Jones, V.P. 1988. Longevity of apple maggot (Diptera: Tephritidae) lures under laboratory and field conditions in Utah. Environmental Entomology, 17:704-708.

Kring, J.B. 1970. Red spheres and yellow panels combined to attract apple maggot flies. Journal of Economic Entomology, 63:466-469.

Neilson, W.T.A., A.D. Knowlton, and R.J. Whitman. 1981. Capture of apple maggot adults on Pherocon, Rebell, and sticky sphere traps. Journal of Economic Entomology, 74:203-206.

Prokopy, R.J. 1968. Visual responses of apple maggot flies, *Rhagoletis pomonella* (Diptera: Tephritidae): orchard studies. Entomologia Experimentalis et Applicata, 11:403-422.

Prokopy, R.J. 1977. Attraction of *Rhagoletis* flies (Diptera: Tephritidae) to red spheres of different sizes. Canadian Entomologist, 109:593-596.

Reissig, W.H. 1975a. Evaluation of traps for apple maggot in unsprayed and commercial apple orchards. Journal of Economic Entomology, 68:445-448.

Reissig, W.H. 1975b. Performance of apple maggot traps in various apple tree canopy positions. Journal of Economic Entomology, 68:534-538.

Reissig, W.H. 1977. Capture of released apple maggot flies, *Rhagoletis pomonella* (Diptera: Tephritidae), on sticky panels. Canadian Entomologist, 109:631-634.

Reissig, W.H., B.L. Fein, and W.L. Roelofs. 1982. Field tests of synthetic apple volatiles as apple maggot (Diptera: Tephritidae) attractants. Environmental Entomology, 11:1294-1298.

Reissig, W.H., B.H. Stanley, W.L. Roelofs, and M.R. Schwarz. 1985. Tests of synthetic apple volatiles in traps as attractants for apple maggot flies (Diptera: Tephritidae) in commercial apple orchards. Environmental Entomology, 14:55-59.

Spangelo, L.P.S. 1971. Hybrid seedling rootstocks for apples. Agriculture Canada Publication 1431.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. 2nd edition, McGraw-Hill, New York. 633 pp.

Swift, F.C. 1982. Field tests of visual and chemical lures for apple maggot flies. Journal of Economic Entomology, 75:201-206.

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RE-EVALUATION OF DEGREE-DAY INDICES FOR PREDICTING SEASONAL ACTIVITY OF THE CARROT RUST FLY, *PSILA ROSAE* (DIPTERA: PSILIDAE) IN ONTARIO

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When seasonal activity of the carrot rust fly (CRF), *Psila rosae* (Fab.), in the Holland Marsh, Ontario, was studied in relation to degree-days (DD) accumulated by various summation methods, the average differences between expected and observed dates of seasonal events over periods of 4 to 8 years varied from 1 to 1.8 days (Stevenson 1983). To determine whether or not the previously published indices remain valid, I have examined more recent CRF seasonal activity data, pooled together with that presented previously, in relation to DD summed by several methods.

The CRF is typically bivoltine in southern Ontario. Seasonal events that were examined in relation to DD summations were first and 50% emergence and first trap catch of adults of the overwintering generation (OWG), and first emergence and first trap catch of first generation (1G) adults.

Seasonal activity data for CRF were obtained as previously described (Stevenson 1983) by placing 2 to 4 emergence cages over sites where infested carrots were growing or had grown in the previous year, or by placing sticky traps (Stevenson 1977), usually 4 per location, in experimental plots or commercial carrot fields. Cages and traps were examined at intervals varying over the years from 1 to 5 days. If the interval between the date of first observance of a seasonal event and the date of the preceding record was greater than one day, and if more than 0.5 adults per cage/trap were present, the date of the event was estimated to be the mid-point between the two dates. Otherwise, the date of examination was taken as the date of the event. The mean maximum possible difference between the estimated dates of events and the true date was less than one day for all events studied (Table I).

Air temperatures were obtained from the Ontario Ministry of Agriculture and Food Muck Research Station (MRS) at Kettleby, Ontario. Cage and trapping sites were never more than 7.5 km distant from the MRS. Soil temperatures were obtained using a Duro® recorder with a probe at 5 cm deep in soil near the emergence cages. DD summations were calculated using the ACTS degree-day programme of Agriculture Canada's Agnet system. Air DD>5°C (DD_5) were summed from 1 March. Soil DD>3°C (DD_3) were summed from 1 April (Stevenson 1983).

The mean DD accumulated to date or estimated date of occurrence of each seasonal event was calculated. Using the mean DD as the index, expected dates of events were determined from the Agnet summations of cumulative DD for each year, and mean differences between observed and expected dates were calculated.

Not all of the indices described previously (Stevenson 1983) were re-examined. There were insufficient data available for re-evaluation of soil temperature indices for 1G activity and summation of air temperature with an upper limit of 20°C also was unavailable. Summations of air temperatures from 1 April rather than from 1 March were examined but as they provided no improvement in predictability, are not discussed here. An index based on DD_5 occurring between the dates of first emergence of OWG and 1G also was examined.

In general, the mean errors in days, ranging from 1.0 to 2.5 (Table I), were higher than those described previously (Stevenson 1983). Based on pooled data for 8 years, the mean DD_3 (soil) to first emergence of 1G CRF was higher (240 DD_3) for 10 years than the previous index based on 4 years data (220 DD_3), however, both indices produced a mean error of 2.0 days for the 8 years studied. The index of 255 DD_5 for first trap catch is very near that reported previously (Stevenson 1983). The Baskerville-Emin (1969) summation did not improve predictability compared with the standard method, but is included here because some computer summations in use may provide only that method.

TABLE I. Degree-day indices for carrot rust fly seasonal events and mean differences between observed and expected dates of events.

Gen.[1]	Event[2]	Temp. source	Summation method[3]	No. of years	Mean DD[4]±SD	Mean error (days±SD)
OWG	1st Emerg.	Soil	Std	8	240±31	2.0±1.0
OWG	50% Emer.	Soil	Std	8	340±13	1.0±0.9
OWG	1st Trap.	Air	Std	11	255±14	1.8±1.0
OWG	1st Trap.	Air	B&E	9	293±16	1.7±1.5
OWG	50% Emer.	Air	Std	8	354±31	2.5±1.5
OWG	50% Emer.	Air	B&E	8	385±36	2.4±1.5
1G	1st Emer.	Air	Std	11	1150±32	1.9±1.2
1G	1st Trap.	Air	Std	13	1142±37	2.0±2.0
1G	1st Emer.	Air	Std	11	D1+888[6] ±39	2.2±1.3

[1] Gen. = generation, OWG = overwintering generation, 1G = first generation.

[2] Emer. = emergence; trap = trap catch.

[3] Std. = standard summation; B&E = Baskerville and Emin (1969).

[4] Base temperature for soil DD, 3°C; base for air temperature 5°C.

[5] Mean maximum possible difference (days) between the estimated date of event and the true date due to sampling interval was: OWG, 1st trap catch, 0.9 days; OWG 1st emergence, 0.6 days; OWG 50% emergence, 0.9 days; 1G 1st emergence, 0.5 days; 1G 1st trap catch, 0.7 days.

[6] D1 = the DD_5 observed in a given year to first emergence of OWG.

The observed mean DD_5 (N=13) to first 1G trap catch (1142) represents a decrease of only 6 DD_5 from the previously reported index (N=7). The index to first emergence based on DD_5 air is not directly comparable to that reported previously (Stevenson 1983), as an upper limit of 20°C was used in the earlier summation. The slightly higher DD_5 (1150) to first emergence of 1G than to first trap catch probably is an anomaly occurring because the two indices were not based on the same exact group of years. Normally, emergence in cages is detected as early or earlier than first trap catch.

When mean errors were rounded off to the nearest day, as would be the case in practice, there was little difference in predictability between indices based on emergence data as compared to field trap catches. Nor did soil temperatures provide an advantage except in regard to 50% OWG emergence. The index based on DD_5 occurring between OWG first emergence and 1G first emergence was not more effective than the one based on DD_5 from 1 March to first emergence of 1G. Therefore, the standard summation of air temperatures above 5°C, summed from 1 March, which is the method commonly used in Ontario, can provide a predictive index for CRF that should be as useful in management programmes as any alternative method.

References

Baskerville, G.L. and P. Emin. 1969. Rapid estimation of heat accumulation from maximum and minimum temperatures. Ecology, 50:514-517.

Stevenson, A.B. 1977. A disposable adhesive trap for monitoring the carrot rust fly. Proceedings of the Entomological Society of Ontario, 107:65-69.

Stevenson, A.B. 1983. Seasonal occurrence of carrot rust fly (Diptera: Psilidae) adults in Ontario and its relation to cumulative degree-days. Environmental Entomology, 12:1020-1025.

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PRESIDENT'S PRIZES* AND STUDENTS' PAPERS, 1989

The **Society** congratulates Joyce Nyhof-Young and Barry Glofcheskie for their exemplary presentations at the 126th Annual meeting, held in London on 27-29 October 1989 which resulted in their both being awarded the President's Prize at the banquet.

The **Society** also congratulates the other student participants in the meetings for the excellent presentations.

Abstracts of all student presentations are given below.

PRESIDENT'S PRIZES

TYROSINE HYDROXYLASE-LIKE IMMUNOREACTIVITY IN THE CENTRAL NERVOUS SYSTEM OF FIFTH INSTAR *RHODNIUS PROLIXUS* (HEMIPTERA: REDUVIIDAE)

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Proc. ent. Soc. Ont. 120:69

The distribution of tyrosine hydroxylase-like immunoreactivity was mapped in whole-mount preparations of the central nervous system (CNS) of fifth instar *Rhodnius prolixus* Stal. Immunoreactivity was limited to neuronal cell bodies and processes, which were distributed over both ventral and dorsal surfaces of the CNS. All ganglia and interganglionic connectives contained immunoreactivity. The greatest number of cell bodies was present in the brain and the fewest in the prothoracic ganglion. A comparison of a map of the distribution of catecholamine-induced fluorescence obtained using the glyoxylic acid technique (Flanagan 1983) with that generated for tyrosine hydroxylase reveals considerable overlap between the two systems. The wide distribution of immunoreactivity suggests that tyrosine hydroxylase is present in neurons with diverse central functions. Tyrosine hydroxylase is the rate-limiting enzyme in catecholamine synthesis in vertebrates. Since many of the immunoreactive neurons in *R. prolixus* have previously ben shown to be catacholaminergic, it would appear that tyrosine hydroxylase is used in the catecholamine pathway in this insect. The mapping of these reactive neurons is an important step for identification of unique tyrosine hydroxylase-containing neurons, and is our initial step in the analysis of identified catecholamine-containing neurons in *R. prolixus*.

MUSCOVY DUCKS AS AN ADJUNCT FOR THE CONTROL OF THE HOUSE FLY (DIPTERA: MUSCIDAE)

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Proc. ent. Soc. Ont. 120:69-70

In laboratory trials, Muscovy ducks (*Cairina moschata* L.) removed adult house flies 30 times faster than four commercial fly control devices (Golden Malrin® fly bait, Moskit® sticky coil, Silva® fly sheet and Fly Terminator® fly trap). The LT_{90} for Muscovy ducks in

$0.24\ m^3$ cages with 100 flies was 0.6 hr compared to 15.3 hr for our best commercial device. Field trials on swine and dairy operations indicated excellent results in enclosed rooms (>85% control) and moderate results in open areas (0-65% control).

STUDENTS' ABSTRACTS

EFFECTS OF PEAT MINING ON THE INSECT FAUNA OF WAINFLEET BOG, WELLAND, ONTARIO

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Proc. ent. Soc. Ont. 120:70

Insects were collected by pan traps at Wainfleet Bog, during the late summer and fall of 1987 and the spring and early summer of 1988, in four zones previously mined and one unmined zone. The "control" zone was affected by draining but was not mined. Mined zones were of varying ages (i.e. years since mining disturbance) between 2 and 25 years. The lists of collected species were compared in terms of species richness, Sorenson's Index of Similarity (Cs values), abundance of individuals, trophic structure, and relative age of zones. The insect community overall was compared to the fauna of a similar, undisturbed *Sphagnum* bog near Arthur, Ontario (Wylde Lake bog). Preliminary results indicate that mining activities at Wainfleet have resulted in a change of faunal composition and community structure. Faunal similarity of zones decreased as difference in age of zones increased. Zones of intermediate age displayed highest similarity, species richness, and abundance of individuals, but the most recently mined zone contained the fewest species and individuals and was least similar to all other zones. Faunal composition and community structure were also found to vary between zones and between Wainfleet and Wylde Lake. Differences in fauna between the disturbed bog and the undisturbed bog included a reduction in species that prefer bog habitat ("bog species"), an increase in "non-bog" species, and a reduction in the ratio of herbivorous to predacious species.

THE INTERACTION OF ACID PRECIPITATION AND FOREST TENT CATERPILLAR (*MALACOSOMA DISSTRIA*) (LEPIDOPTERA: LYMANTRIIDAE) DEFOLIATION ON SUGAR MAPLE (*ACER SACCHARUM*)

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Proc. ent. Soc. Ont. 120:70-71

The combined effects of defoliation and simulated acid precipitation on 6-7 year old sugar maple (*Acer saccharum* Marsh.) saplings were examined under controlled greenhouse conditions. Trees were sprayed twice weekly in simulated precipitation chambers over two consecutive growing seasons. Each spraying event consisted of a 12.5 ml application of either simulation rain SR (pH 5.6) or simulated acid rain SAR (pH 3.2) solution.

Parameters including height and stem diameter were used to compare growth rates of the trees being sprayed. Additional comparisons were made to 50%, 75% and 100% artificially defoliated trees treated with SAR, and forest tent caterpillar FTC (*Malacosoma disstria* Hübner) defoliated trees (100%) sprayed with SR and SAR. There was no significant difference in growth between sugar maples treated with pH 3.2 or pH 5.6 solution. Trees defoliated both artificially at 75% and 100%, and by FTC (100%) experienced significant growth reductions.

Growth rates of FTC larvae exposed to either acid or non-acid treated foliage was also examined. Larvae reared in plastic cages were provided a diet consisting initially of leaf discs and later whole leaves taken from trees sprayed with SR or SAR. There was a significant difference in both the rate of development and final weight of FTC. Larvae feeding on the acid treated foliage pupated earlier and weighed more than larvae reared on non-acid treated foliage.

POPULATION DYNAMICS OF ANT-MEDIATED SEED DISPERSAL

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Proc. ent. Soc. Ont. 120:71

Over the course of the past several decades, population ecologists have become increasingly aware of the importance of mutualistic interactions in structuring natural communities and ecosystems. One such interaction is myrmecochory, a phenomenon whereby certain species of herbaceous plants produce seeds which contain special structures to attract ants and facilitate dispersal. A general introduction to myrmecochory is presented as background to a discussion of attempts to construct and test a computer-based model simulating the behaviour of populations of myrmecochorous plants.

ORIGINS OF THE SPHAEROCERIDAE (DIPTERA) OF THE QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA

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Proc. ent. Soc. Ont. 120:71-72

Distributional patterns of the Sphaeroceridae (Diptera) of the Queen Charlotte Islands were examined in order to test the long-standing hypothesis that the archipelago was the site of a Wisconsinan glacial refugium. A total of 27 species of sphaerocerids were collected on the islands in 1988. Of these, 10 species show a widespread Holarctic distribution, 4 species are widespread across North America, 7 species are restricted to North America west of the Rocky Mountains, 3 species are restricted to the coastal forest west of the Coast Range, and 3 species are supralittoral along the coast. There is no indication of endemism or relict distributions on the islands; the sphaerocerid fauna is similar to that found on the adjacent mainland. The most parsimonious explanation for the origin of the present fauna of the archipelago is post-glacial colonization from mainland North America. The sphaerocerid

distribution pattern was compared with patterns for other acalyptrate Diptera collected during 1988, as well as published lists of Diptera and Coleoptera from the region. In general, other insect taxa corroborate the pattern seen in the Sphaeroceridae, with post-glacial dispersal from mainland source areas accounting for the present insect fauna of the Queen Charlotte Islands.

THE EFFECT OF INHIBITORS OF ARACHIDONIC ACID METABOLISM ON TREHALOSE EFFLUX FROM COCKROACH, *PERIPLANETA AMERICANA*, FAT BODY

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Proc. ent. Soc. Ont. 120:72

The objective of this study was to determine whether inhibition of arachidonic acid metabolism would affect the efflux of trehalose from the American cockroach, *Periplaneta americana* L. (Dictuoptera: Blattidae), fat body. Inhibitors of phospholipase A$_2$ (mepacrine and 4-bromophenacyl bromide) which decrease the release of arachidonic acid from phospholipids in mammalian tissues, decreased corpus cardiacum stimulated trehalose efflux. On the other hand, melittin, which activates phospholipase A$_2$ thereby increasing the release of arachidonic acid from phospholipids, stimulated trehalose efflux. Inhibitors of the cyclooxygenase (diclofenac, indomethacin) and lipoxygenase (nordihydroguaiaretic acid) which inhibit metabolism of arachidonic acid by these respective pathways, decreased hormone stimulated trehalose efflux. Indomethacin was inhibitory to the increase in trehalose efflux mediated by melittin. These experiments suggest that the release and metabolism of arachidonic acid may be linked to the stimulation of trehalose efflux by corpus cardiacum hormones.

PHOSPHATIDYLINOSITOL METABOLISM AS A MEDIATOR OF CORPUS CARDIACUM ACTION IN THE INSECT FAT BODY

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Proc. ent. Soc. Ont. 120:72-73

This study has shown that corpus cardiacum extract and the purified hormones, CC I and CC II stimulate the production of inositol 1,4,5-trisphosphate in the fat body of the American cockroach, *Periplaneta americana* (L.) (Dictuoptera: Blattidae). Inositol 1,4,5-trisphosphate (IP$_3$) is a known second messenger, which releases calcium from intracellular stores when a specific agonist binds to a cell receptor. CC extract was shown to increase IP$_3$ production in whole fat body tissue by 300% after 5 minutes. The purified hormones, CC I and CC II increased IP$_3$ production maximally after 1 minute by 190% and 250% respectively, in isolated fat body trophocytes. This increase in inositol phosphate production was independent of extracellular calcium. However, CC II-stimulated IP$_3$ production was dependent on intracellular calcium. Intracellular calcium was sequestered using Quin 2, and

CC II seemed to be more effective in producing IP_3 at lower calcium levels. CC I-stimulated IP_3 production was unaffected by Quin 2.

The results suggest that inositol 1,4,5-trisphosphate mediates the action of CC I and CC II in the fat body of *P. americana*. However, the membrane events for IP_3 production may be different for the two hormones.

STRUCTURAL CHANGES IN THE BRAIN OF *AEDES AEGYPTI* (DIPTERA: CULICIDAE) DURING METAMORPHOSIS

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Proc. ent. Soc. Ont. 120:73

Metamorphosis of the yellow fever mosquito *Aedes aegypti* (L.) lasts 2-4 days. The structural changes of the brain at this stage reflect the modification of sensory reception, most notably to visual and chemosensory stimuli. The optic lobes are known to show a large increase in size to accommodate the developing compound eyes. In each antennal nerve bundle, an increase of from 27-28 axons ni the larva to 6,000-7,000 axons in the adult female and 13,500-16,000 axons in the adult male is known. Other changes noted are an increase in brain size relative to that of the head capsule, especially in the volume of the neuropile, as well as a decrease in the size of the pharyngeal foramen because of massive thickening of the circumesophageal connectives. To provide a more detailed description of the histological changes within the brain, semi-thin (0.5 μ) sections were examined from pupae of specific ages. This, combined with studies of the brain of the larva and adult provides a more detailed understanding of the central nervous system of this species.

SODIUM-DEPENDENT L-GLUTAMATE COTRANSPORT IN EPIDERMAL CELLS OF *TENEBRIO* (COLEOPTERA: TENEBRIONIDAE)

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Proc. ent. Soc. Ont. 120:73-74

Epidermal cells of mealworm (*Tenebrio molitor* L.) have the ability to retrieve L-glutamate when it is added to the surround saline. The uptake of L-glutamate is electrogenic and shows an initial depolarization and transient recovery of the membrane potential. Both the depolarization of epidermal cells by L-glutamate and uptake of the tritiated L-glutamate depends on sodium. This suggests that the uptake mechanism cotransports sodium with the glutamate in a combination which would explain the electrogenicity (i.e. $2Na^+$ for each glutamate anion). Tritiated L-glutamate uptake shows typical saturation kinetics with 1/2 maximal uptake at 50μM. L-glutamate uptake is also dependent on the external sodium concentration with 1/2 maximal uptake at 28μM sodium. The L-glutamate transporter efficiently removes 250μM L-glutamate from the bathing solution for up to 6 hours.

L-glutamate uptake occurs in other tissues of the mealworm but the epidermis has the highest rate of uptake. L-glutamate uptake into epidermal cells is also present in locust (*Locusta migratoria* L. (Orthoptera: Acrididae)) epidermis (1/2 maximal uptake 35µM) and cockroach (*Periplaneta americana* (L.) (Dictuoptera: Blattidae)) epidermis. These results implicate the epidermis as a good candidate for maintaining low levels of L-glutamate, allowing it to function as an excitatory amino acid at insect neuromuscular junctions.

REPRODUCTIVE BEHAVIOUR OF THE GREATER WAX MOTH, *GALLERIA MELLONELLA* (LEPIDOPTERA: PYRALIDAE)

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Proc. ent. Soc. Ont. 120:74

The greater wax moth, *Galleria mellonella* (L.), is an important pest of apiaries. The larval stage of this species can cause serious economic damage to brood comb and honey comb either in active colonies or in storage facilities. Studies of wax moth behaviour have revealed that adult females approach males for courtship and copulation. This contrasts with the typical situation observed in Lepidoptera in which males search for signalling females. Male greater wax moths produce a pheromone which is released from a gland at the base of the male's forewing. Behavioural studies determined the role of this male-produced pheromone and other mating cues in the steps leading to pairing and copulation. Wax moths were observed under laboratory conditions at 25°C, during the first six hours of the scotophase. Virgin females were released into a chamber with 2 virgin males of the same age. Behaviours were recorded for 15 min. Forty-five of 50 trials resulted in successful copulation attempts. During courtship, females always approached stationary males by running or crawling while wing-fanning. Stationary males did not display a specific posture or movement to attract females. Females approached the males from the posterior end and assumed a stationary posture while the males circled behind them, wing-fanned and mounted. Visual or olfactory cues, or both, are implicated in the female's search for a mate. Wing-fanning by both males and females appears to be important during the courtship sequence. Further studies address the specific role of the male-produced pheromone.

THE ROLE OF STIGMAEIDS (ACARI) IN THE ORCHARD ACARINE SYSTEM

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Proc. ent. Soc. Ont. 120:74-75

Stigmaeid mites, particularly *Zetzellia mali* (Ewing), are frequently observed in commercial apple orchards in Ontario, but their role in the acarine ecological system has yet to be clearly defined. They prey on both *Panonychus ulmi* (Koch), the European Red Mite (ERM), and *Aculus schlechtendali* (Nal.), the Apple Rust Mite (ARM). However, stigmaeids may interfere with control of these pests by phytoseiid mites. I have examined this potential for interference by comparing stage-specific predator preferences. My comparison of *Z. mali* and the phytoseiid *Typhlodromus caudiglans* (Schuster) has revealed that there is little direct predation between predator species and relatively little overlap between predator preferences for ERM stages. I constructed a one-day functional response model which illustrates that a combination of 1 stigmaeid and 1 phytoseiid per leaf is almost as efficient as 2 phytoseiids for controlling ERM at low prey densities. This is surprising because the maximum phytoseiid feeding rate is about four times that of stigmaeids. There are two factors responsible: less competition within the combination and relatively higher efficiency of a "weak" predator at low prey densities. I am incorporating the functional response model into a four species system model to determine how these short-term interactions relate to the long-term population dynamics of the system.

NEEM-BASED ANTIFEEDANTS AND THEIR EFFECT ON EUROPEAN CORN BORER (*OSTRINIA NUBILALIS* (LEPIDOPTERA: PYRALIDAE))

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Proc. ent. Soc. Ont. 120:75

Neem oil extracted from the neem tree (*Azadirachta indica* A. Juss. (Meliaceae)) and azadirachtin, a triterpenoid purified from neem seeds, were evaluated in field trials for their antifeedant and insecticidal properties to the European corn borer (*Ostrinia nubilalis* Hübner) in sweet corn. Corn plants artificially infested with egg masses of corn borer showed that cobs were significantly less damaged when treated with neem oil - 1.56 kg/ha (13.7 damaged kernels per cob) when compared to an infested control (33.5 damaged kernels per cob). When compared to ambush - 0.015 kg permethrin/ha, neem oil did not exhibit an insecticidal effect on the corn borer larvae; the number of larvae remaining on neem-treated cobs was twice that on ambush-treated cobs.

In controlled laboratory studies, antifeedant activities of azadirachtin and the formulation used in the field (azadirachtin, piperonyl butoxide (PBO) and citowet) were tested in a leaf-disk bioassay. At 7.2 ng/mm azadirachtin, feeding by third instar larvae was significantly reduced when compared to the control but no synergistic effect of PBO with azadirachtin was observed. Growth and development parameters of larvae placed on diet-treated with various neem oil concentrations (azadirachtin content = 2.0-2.5 mg/g oil) showed that maximal larval weights were severely reduced at 1000 and 100 ug/ml. The larval period increased with neem content and was accompanied by abnormalities in larval development such as inability to moult or pupate. The data suggest that neem may offer a safer alternative to the use of synthetic pesticides in controlling the European corn borer in sweet corn.

TOXICOLOGY OF THE PHOTOACTIVE INSECTICIDE, α-TERTHIENYL, IN MOSQUITO LARVAE (DIPTERA: CULICIDAE)

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Proc. ent. Soc. Ont. 120:76

Mosquito larvae were examined to determine interspecific and interstrain differences in susceptibility to the larvicidal effects of the plant-derived phototoxin, alpha-terthienyl (α-T). LC_{50} values were as follows: *Aedes aegypti* (L.), 4 ppb; *Ae. epactius* Dyar and Knab, 6 ppb; *Anopheles stephensi* Liston, 14 ppb; malathion susceptible *Culex tarsalis* Coquillet (S), 12 ppb; malathion-resistant *Cx. tarsalis* (R), 16 ppb. Fluorescence studies indicated localization of α-T in the midgut epithelium and in the lumen of Malpighian tubules. Rates of elimination of tritiated α-T differed significantly between *Ae. aegypti* and *Cx. tarsalis* (S) larvae. Rate of ^{3}H-α-T elimination was inversely correlated with susceptibility to the toxic effects of the compound. Analysis of excreted material using organic/aqueous solvent partitioning indicated that water soluble ^{3}H-α-T metabolites were being eliminated by the insect. The toxicological significance of selective α-T accumulation and the importance of α-T elimination in determining sensitivity are discussed.

THE INSECTICIDAL PROPERTIES OF ASIMICIN, AN ACETOGENIN

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Proc. ent. Soc. Ont. 120:76

F020, a purified extract from the bark of the pawpaw (*Asimina triloba* (L.) Dunal (Annonaceae)) containing the linear acetogenin asimicin, was investigated as a biologically active substance to *Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae), the European corn borer. The F020 in the diet induced mortality and growth inhibition in those larvae which fed on it. This appeared to be the result of a post-digestive effect; however, histological examination revealed that some gut toxicity was apparent. Molting difficulty observed in the Lepidoptera may be attributed to the juvenile hormone-like activity of F020 observed after topical application to *Oncopeltus fasciatus* (Dallas) (Hemiptera: Lygaeidae). The effects of this novel plant product observed in the present study represent one of the first investigations of acetogenins as a class of natural insecticides and may lead to the development of a useful pest control agent.

EFFECTS OF A SYNTHETIC PYRETHROID ON THE MITE (ACARI) COMPLEX IN APPLE ORCHARD

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Proc. ent. Soc. Ont. 120:77

The effects of PP321, a new synthetic pyrethroid on phytophagous mites and predatory mites were studied over two years in the apple orchard at the Smithfield Experimental Farm of Agriculture Canada. No direct effectiveness of PP321 on European Red Mite (ERM), *Panonychus ulmi* (Koch), and Two Spotted Spider Mite (TSSM), *Tetranychus urticae* Koch, were found. Populations of *Zetzellia mali* (Ewing) and phytoseiids were strongly suppressed by the synthetic pyrethroid PP321. These predatory mites can effectively suppress the populations of ERM and TSSM when the former's density reaches relative high levels. Another phytophagous species, the Apple Rust Mite (ARM), *Aculus schlechtendali* (Nal.), was more abundant on control blocks than on chemically treated ones. The possibility of development of resistance to synthetic pyrethroid in predatory mites under apple orchard conditions is being explored.

IMPACT OF PULSE EXPOSURE TO SELECTED INSECTICIDES ON LARVAE OF *AEDES AEGYPTI* (DIPTERA: CULICIDAE): IMPORTANCE OF EXPOSURE DURATION

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Standard tests aimed at evaluating the acute toxicity of a pesticide to aquatic organisms typically involve exposures for 24-96 hours. However, in natural situations, aquatic organisms may encounter a pesticide for only a short period of time (i.e. a few hours). Because exposure duration can influence toxicity, knowledge of the relationship between exposure duration and toxicity aids in making more accurate predictions of environmental impact. My study examined the relationship between exposure duration and toxicity of permethrin, fenitrothion, and carbaryl to larvae of *Aedes aegypti*.

Third instar larvae were exposed to the above insecticides for periods between 0.25 and 24 hrs, after which they were transferred to clean water and the survivors reared to adults. Observations were made at 24 hr intervals to assess recovery and delayed mortality. Some larvae showing symptoms of permethrin and carbaryl poisoning after 0.25 - 1 hr exposure were able to recover when placed in clean water. There was no recovery from symptoms of fenitrothion poisoning. Acute toxicity increased significantly with increasing exposure for each insecticide. The toxicity of two 1 hr exposures separated by 6 hrs in clean water was not significantly different from a continuous 2 hr exposure.

THANKS TO SPONSORS OF 1989 ANNUAL MEETING

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